DOCUMENT RESUME

ED 289 720 SE 048 805

AUTHOR Lunde, Paul; And Others
TITLE Science: The Islamic Legacy.
PUB DATE 86
NOTE 69p.; Colored photographs may not reproduce well.
AVAILABLE FROM Aramco Services Company, Box 4534, Houston, TX 77210 (free while supply lasts).
PUB TYPE Historical Materials (060) -- Collected Works - Serials (022)
JOURNAL CIT Aramco World Magazine; spec iss 1986

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Astronomy; *Foreign Countries; *Islamic Culture; Middle Eastern Studies; *Religion; *Science and Society; *Science History; Sciences; Space Sciences; *Technological Advancement
IDENTIFIERS Saudi Arabia

ABSTRACT

In the wake of the first space voyage and in-flight experiments by a Muslim astronaut, this document focuses upon the story of Islamic science through the ages. It is intended to demonstrate the resurgence of scientific research and technological development in the Muslim world. The booklet contains chapters on: (1) science: the Islamic legacy; (2) science in the golden age; (3) the book of animals; (4) science in al-Adnalus; (5) the Bodleian tribute in the Oxford Library; (6) science, the modern age; (7) Arabs and astronomy; and (8) science in the space age. (TW)

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Science: The Islamic Legacy

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ARAMCO WORLD magazine

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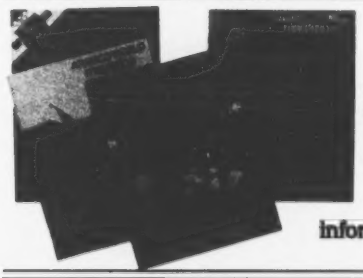
It is particularly timely – in the wake of the first space voyage and in-flight experiments by a Muslim astronaut – that *Aramco World magazine*, tell, in this special issue, the story of Islamic science through the ages. It is also appropriate. The twin themes of the 1986 Vancouver World Fair are transport and communications – two fields in which, by journeying into space and launching their first communications satellite, the Arabs show the resurgence of scientific research and technological development in the Muslim world.

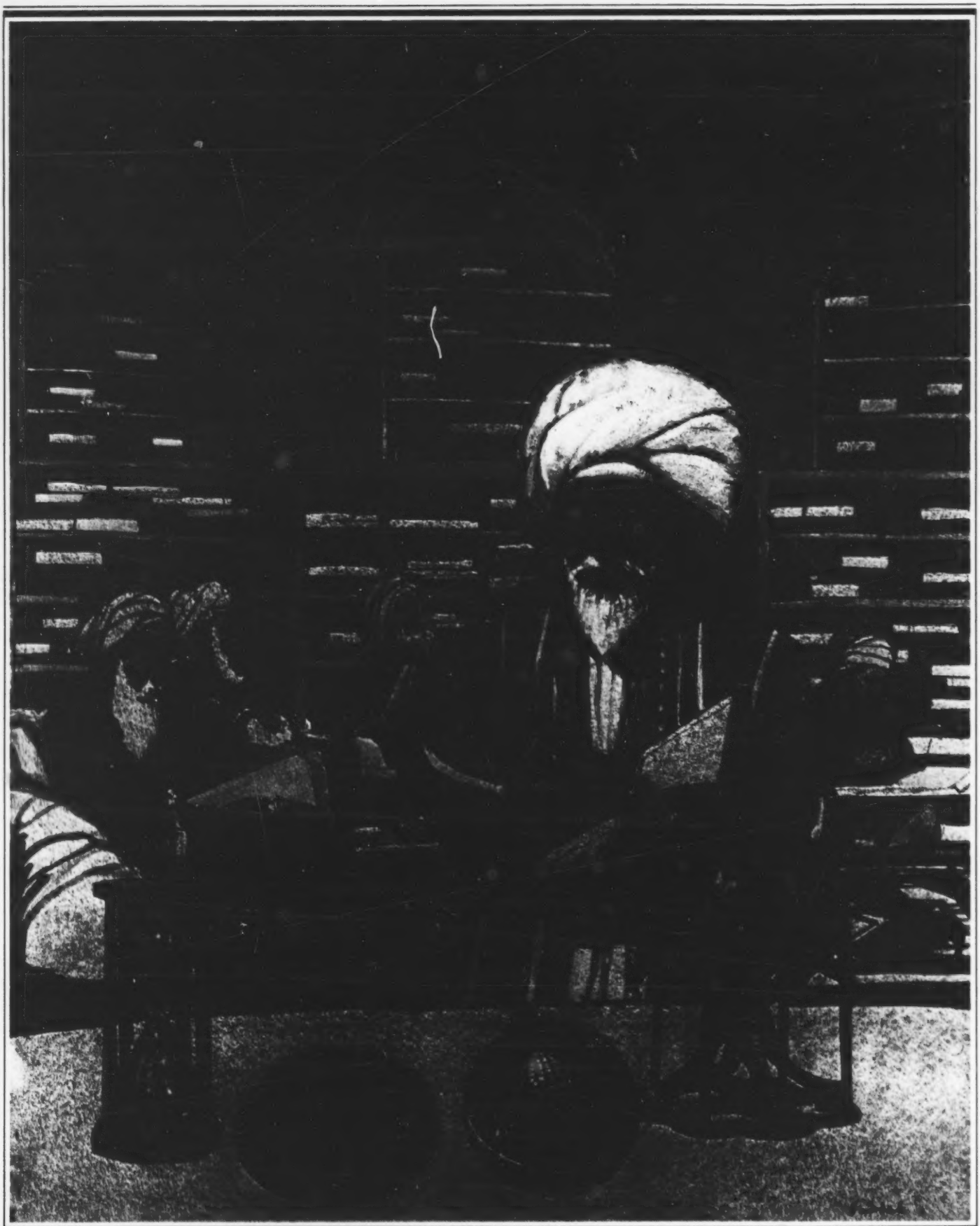
The Editors



***Aramco World magazine* is an educational publication focusing on the history, art, economy, science, geography, and ecology, customs, cultures and peoples of the Arab East and the Islamic world. Though its circulation is limited, subscriptions to the magazine are available, on request, to anyone with a specific interest in the Middle East. Reprints of some articles are occasionally available as well. For information and subscriptions please write to the Editor, Plesmanlaan 100, Leiden, The Netherlands.**

Front Cover: An Islamic Legacy; Science in the Space Age (Design by Peter Keenan from transparencies by Tony Stone, Worldwide). *Back Cover:* A university laboratory in Saudi Arabia (S. M. Amin). *Inside Front Cover:* A symbol of technological growth; aluminium for construction projects (Amin). *Inside Back Cover:* The first Arab communications satellite (Aerospatiale). *Page 2:* Scholars at the House of Wisdom (Michael Grimsdale). *5:* Illustration from the Ambrosiana manuscript of Jahiz' *Book of Animals* (Courtesy Ambrosiana Library, Milan). *6:* Arab astronomers (Grimsdale). *8:* Water clock designed by 13th-century engineer al-Jazari (Grimsdale). *9:* Use of precise weights in buying and selling (Grimsdale). *10:* Geometric tile decoration from palace in Marrakesh (Grimsdale). *11:* Manuscript of Arabic translation of Euclid's *Elements* (Courtesy Bodleian Library, Oxford University). *12:* Al-Biruni explains the chessboard problem (Grimsdale). *13:* An Egyptian water-wheel (Grimsdale). *Pages 14/15/16/17/18/19:* Illustrations from the Ambrosiana manuscript of Jahiz' *Book of Animals* (Courtesy Ambrosiana Library). *20:* A pharmacist prepares a cure (Grimsdale). *21:* Stucco dome from al-Andalus (Tor Eigeland). *23* A medieval library (Grimsdale). *24:* Manuscript of the Latin translation of al-Zahrawi's *Tasrif* (Courtesy Bodleian Library). *25:* Manuscript of Arabic translation of Dioscorides (Courtesy Bodleian Library). *26:* Windmills in Khurasan (Grimsdale). *27:* Metallurgy in medieval Cairo (Grimsdale). *28:* Title page of manuscript of Avicenna's famous *Canon of Medicine; 29:* Latin translation of Arabic scientific work; *30:* Manuscript of Arabic work on geometry; *31:* A Middle English treatise on the astrolabe; *32:* (Left) A Latin treatise on the astrolabe; (Center) Latin translation of Arabic scientific work; *33:* The constellation Orion, from an Arabic manuscript on the stars. (All courtesy Bodleian Library). *34:* Saudi Arabia's University of Petroleum and Minerals (UPM) (Amin). *35:* Saudi graduates from U.S. university (Katrina Thomas). *36:* Saudi science student (John Champney). *37:* Surgery at King Faisal Specialist Hospital in Riyadh (Terry Webb). *38:* Agricultural experiment in Syria (Nik Wheeler). *39:* Irrigation discs in Oman (Eigeland). *40:* Students at King Sa'ud University (Robert Azzi). *41:* Computerisation in Saudi Arabia (Amin) *42:* Satellite image of Arabian Peninsula (NASA).*43:* University of Petroleum and Minerals, Dhahran (Amin). *44:* Solar experiments on the Arabian Peninsula (Burnett H. Moody). *45:* Raceway fish rearing at the Kuwait Institute of Scientific Research (Moody). *46:* King Fahd and Shaikh Zaki Yamani, the Minister of Petroleum and Minerals, at opening of Aramco's EXPEC buildings in Dhahran (Amin). *47:* The new engineering (right) and EXPEC buildings (left), Dhahran (A. Dobais). *48:* The Hajj terminal at Jiddah airport (Amin). *49:* King Khalid International Airport mosque in Riyadh (Moody). *50:* 'Abbas ibn Firnas' model of the planetary system (Grimsdale). *52/53:* Medieval Muslim scholars (Grimsdale). *54:* The *Discovery* heads for space with an Arab prince and Arab satellite (Moody). *55:* Prince Sultan, the first Arab astronaut (NASA). *56:* In space Prince Sultan participates in weightless experiment (NASA). *57:* (Above) The prince during the *Discovery* flight in June 1985 (NASA). (Below) King Fahd, in Riyadh, talks to Prince Sultan in space (WTN). *58:* (Above) King Fahd welcomes Prince Sultan's return to earth (WTN). (Below) Prince Sultan presents T-Shirt to President Reagan (P. Souza A.P.). *59:* An Arabsat satellite undergoing pre-flight check (Aerospatiale). *60:* An Ariane rocket carries Arabsat-A into space (WTN). *61:* Arabsat-B being launched from the *Discovery* (NASA). *62:* Riyadh communications tower (J. Nieman-Susan Griggs Agency). *63:* The London bureau of KUNA, the Kuwaiti news agency (Nieman).*64:* Tracking station on Arabian Peninsula.

Published by Aramco, a Corporation, Suite 1200, 1667 K Street, N.W. Washington, D.C. 20006. John J. Kelberer, Chairman of the Board and Chief Executive Officer; Ali I. Naimi, President; Fahad M. Ghaslaan, Treasurer; Paul F. Hoye, Editor



Science : The Islamic Legacy

WRITTEN BY PAUL LUNDE PAINTING BY MICHAEL GRIMSDALE
REPRODUCTION FROM *THE BOOK OF ANIMALS* COURTESY THE AMBROSIANA LIBRARY, MILAN

The Arabs were the inheritors of the scientific tradition of late antiquity. They preserved it, elaborated it, and, finally, passed it on to Europe.

The story of how this came about is far from simple, and much research needs to be done before its details are completely understood, but the broad outlines are clear.

When Egypt, Palestine, Syria, Iraq, Asia Minor and Persia fell to Islamic forces in the seventh century they included a heterogeneous population. Although the cultivated classes of the former provinces of the Byzantine Empire spoke Greek, the people spoke a number of other languages – Coptic in Egypt and various Aramaic dialects in Syria and Iraq. These populations were for the most part Christian. In Persia, the majority language was Pahlavi – an earlier form of the language spoken there today – and the state religion was Zoroastrianism, with substantial Christian minorities and a few centers of Buddhism.

Throughout this immense area, there were two main scientific traditions. The first, and by far the most important, was that of Greece. The second was that of India, strongest in Persia because of the geographical proximity of the two countries.

At a surprisingly early date, the Arab ruling dynasty of the Umayyads, with its capital at Damascus, evinced an interest in Greek science. The little Umayyad audience hall and bath of Qasr 'Amra, built in the Syrian desert around A.D. 711 – only 79 years after the death of the Prophet Muhammad – contains, on the inside of the dome, a painted representation of the zodiac made on a stereographic projection, perhaps showing a familiarity with the methods of Ptolemy. The same room contains paintings of personifications of History, Poetry and Philosophy; each figure is labeled in Greek.

The interest of the Umayyads in Greek science attested by the paintings at Qasr 'Amra is confirmed by early Muslim historians, who record the experiments in alchemy made by Khalid ibn al-Yazid, a grandson of the first Umayyad caliph Mu'awiya.

Astronomy and alchemy were thus the first sciences to preoccupy the Muslims. It is noteworthy that they were also typical of the interests of the Greek scholars of late antiquity, particularly of those in Alexandria. In fact, it was to be this tradition, with its emphasis on mathematics, physics, astronomy and medicine, that was to be most fruitfully elaborated by Muslim scientists.

Although the great library of Alexandria, repository of the learning of the classical world, no longer existed at the time of the Arab conquests, the works of many of the Greek scholars who studied there now exist only in Arabic translation. How did this come about? How did the Arabs, who had little or no *direct* contact with Greek science, and in any case were unfamiliar with the Greek language, gain their very detailed knowledge of it?

The answer to this question lies in the continued presence of a Greek-speaking (or reading) educated class among the subject populations of the Muslim empire. When the Umayyad dynasty–the language of whose administration, until A.D. 699, was Greek – was supplanted by that of the Abbasids in A.D. 750, the center of the empire shifted eastward. A new capital, Baghdad, was built in Iraq on the banks of the Tigris. Here, not far from the old Persian capital of Ctesiphon, the character of the empire changed.

Although the Umayyads had made use of non-Arab, Greek-speaking civil servants, they had remained firmly Arab in their tastes and philosophy of rule, and had made little effort to attract the subject population to the religion of Islam. Now, all this was changed; the Abbasids from the beginning conceived of an Islamic polity based on religious affiliation rather than national origin. Baghdad became an international city, where Persians, Indians, Greeks, Sogdians – from beyond the Oxus – Armenians, Turks, Jews and Arabs lived side by side. This inevitably led to a mingling of varied intellectual traditions; at the same time, the language of the court – and increasingly of the people – was Arabic.

The Arabic-speaking intelligentsia of Baghdad were of course aware, through their contacts with Greek-speaking Muslims and Christians, of the great achievements of classical scientists. The university of Gondeshapur, the great intellectual center of Sassanid Persia, was not far from Baghdad. When the Council of Ephesus in 431 excommunicated Nestorius, his followers sought refuge in Persia, where the Sassanid Shahs welcomed them. The Nestorians brought with them a knowledge of two sciences which were, with their help, later to be cultivated by the Muslims – medicine and astronomy.

Science : The Islamic Legacy

Another Christian sect, the Monophysites, fleeing Byzantine persecution 20 years later, also settled in Persia, as well as in Syria, where they founded schools at Edessa, Nisibis, Antioch and Beirut, where law and rhetoric were particularly studied. These two disciplines were also later to become fruitful areas of Muslim scholarship.

There was, therefore, no complete rupture between the late classical and the Muslim world, as far as the scientific tradition was concerned. A Greek-speaking physician like Alexander of Tralles, who was active at about the time the Prophet Muhammad was born – around A.D. 570 – wrote a standard medical textbook which was later translated into Arabic and eventually from Arabic into Latin, and had considerable influence on medieval European medical practice. One of the most striking confirmations of this continuity is the fact that the Alexandrian Academy survived, albeit in shadowy form, into Islamic times, when it was moved to Antioch, where enrollment fell until only one professor and two students were left. One of these students in turn taught one of the foremost Abbasid translators, while the other taught a student who in turn instructed one of the greatest Arab philosophers, al-Farabi.

The Indian scientific tradition mingled with that of Greece at Gondeshapur and other centers of Christian learning in Persia. The Indians were particularly concerned with mathematics, astrology and the scientific study of grammar. About the year 600 – during the lifetime of the Prophet Muhammad – Indian mathematicians developed the symbol zero and the system of place notation. This invention, first mentioned in the Islamic cultural area in a Syriac text written in A.D. 662, when the Umayyad caliph Mu'awiya was ruling in Damascus, revolutionized the study of mathematics and made possible the great achievements of Muslim mathematicians.

It was during the early Abbasid period, however, that the tentative beginnings made under the Umayyads blossomed into a true scientific renaissance. Several of the early Abbasid caliphs made a systematic effort to translate Greek and Indian scientific texts into Arabic.

This effort began during the reign of the second Abbasid caliph, al-Mansur, who founded Baghdad and ruled from A.D. 754 to 775. Al-Mansur sent embassies to the Byzantine emperor to ask for Greek mathematical texts – in particular for the *Elements* of Euclid; the famous al-Ma'mun, later did the same. Ibn Khaldun, writing in North Africa in the 14th century, but making use of a wide variety of earlier sources, describes the remarkable efforts made by these caliphs to enrich the intellectual life of the Muslim community:

> When the Byzantine emperors conquered Syria, the scientific works of the Greeks were still in existence. Then God brought Islam, and the Muslims won their remarkable victories, conquering the Byzantines as well as all other nations. At first, the Muslims were simple, and did not cultivate learning, but as time went on, and the Muslim dynasty flourished, the Muslims developed an urban culture which surpassed that of any other nation.
>
> They began to wish to study the various branches of philosophy, of whose existence they knew from their contact with bishops and priests among their Christian subjects. In any case, man has always had a penchant for intellectual speculation. The Caliph al-Mansur therefore sent an embassy to the Byzantine emperor, asking him to send him translations of books on mathematics. The emperor sent him Euclid's *Elements* and some works on physics.
>
> Muslim scholars studied these books, and their desire to obtain others was whetted. When al-Ma'mun, who had some scientific knowledge, assumed the caliphate, he wished to do something to further the progress of science. For that purpose, he sent ambassadors and translators to the Byzantine empire, in order to search out works on the Greek sciences and have them translated into Arabic. As a result of these efforts, a great deal of material was gathered and preserved.

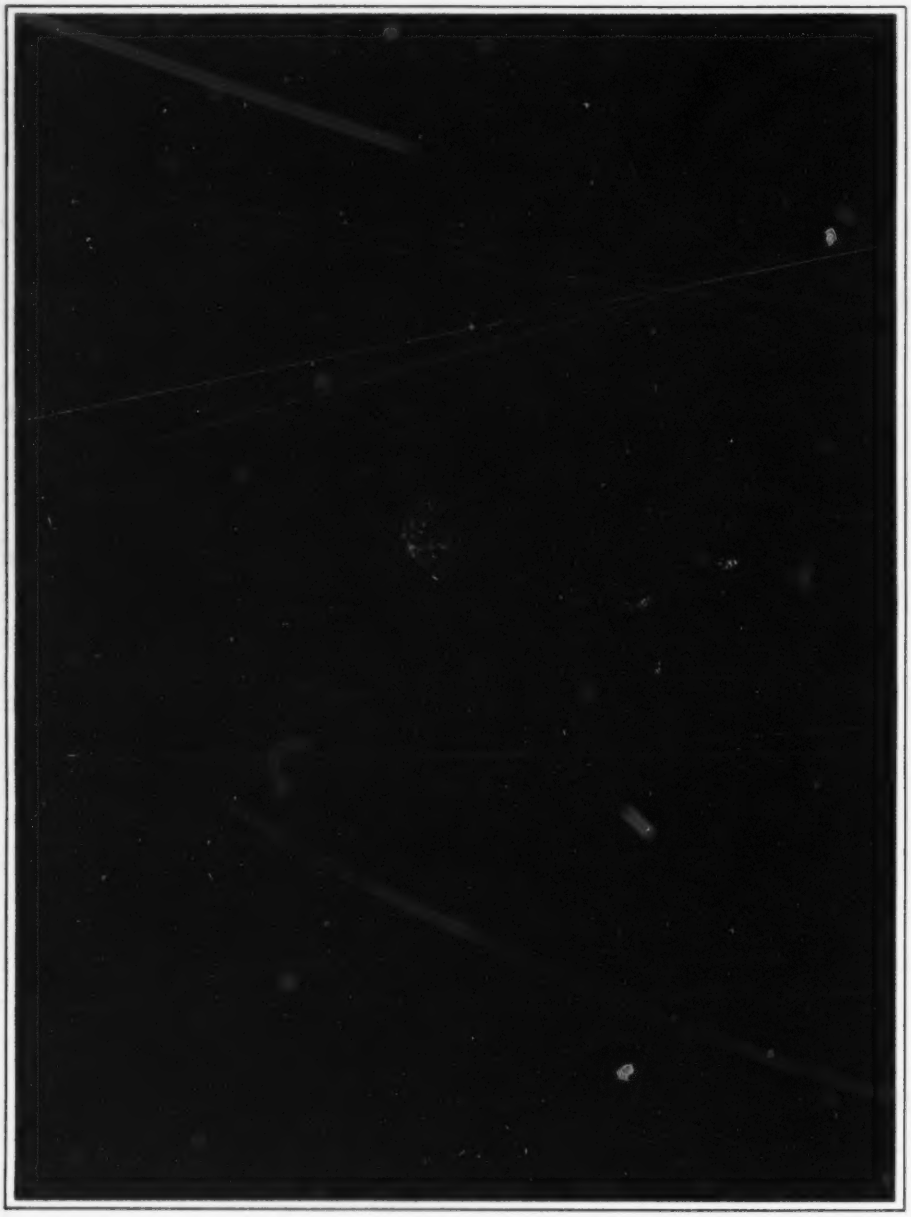
Other Muslim historians record the arrival of an Indian scientist named Manka at the Abbasid court in A.D. 770, and he seems to have had a considerable influence on the mathematicians and astrologers of Baghdad, although we know little of the precise nature of this influence.

Under al-Ma'mun, a more systematic effort was made to translate Greek scientific texts into Arabic. He founded an institute for the purpose, called the *Bait al-Hikma*, The House of Wisdom, and staffed it with salaried Christian and Muslim scholars. The work of translation was complex. Christian translators first rendered the Greek texts into Syriac, the language with which they were most familiar. These preliminary versions were then put into Arabic, with Muslim Arabic-speakers correcting them for style.

Muslim scientists were much influenced by the Greek notion that the science of mathematics was the key to all other sciences. Aristotle, whom the Arabs called "The Foremost Teacher," had inscribed above the door of his house: "Let no one enter who does not have a knowledge of mathematics." This could equally well serve as a motto for the House of Wisdom. We have seen that one of the first Greek books brought to Baghdad from Constantinople was a copy of Euclid's *Elements*. This was translated into Arabic a number of times, as were several of the Greek commentaries upon it, in particular that of the inventor and mathematician, Hero of Alexandria, whose experiments with automata in the third century B.C. were to be so strangely echoed by Muslim scientists. As late as the 13th-century, Nasir al-Din al-Tusi wrote a detailed commentary on the *Elements*, which was among the first Arabic texts to be printed in the original in 16th-century Italy.

Many other Greek mathematical works found their way into Arabic through the efforts of the scholars at the House of Wisdom and their successors. Euclid, Apollonius of Perga, Nichomachus of Gerasa – the magnificent classical ruin presently called Jerash, in Jordan – Menelaus, Archimedes and Theodosius of Tripoli were all translated at an early date, as were works by astronomers like Ptolemy, Autolycus, Dorotheus, Aristarchus, Hipparchus, Theon of Alexandria, Aratus and Geminus of Rhodes. A number of these works were later translated into Latin and Hebrew and thus became known to medieval Europe.

The exact sciences – mathematics, astronomy and optics – perhaps occupied pride of place for Muslim scholars, but the natural sciences, particularly medicine and its ancillary disciplines, were also assiduously cultivated. Again, the first phase was



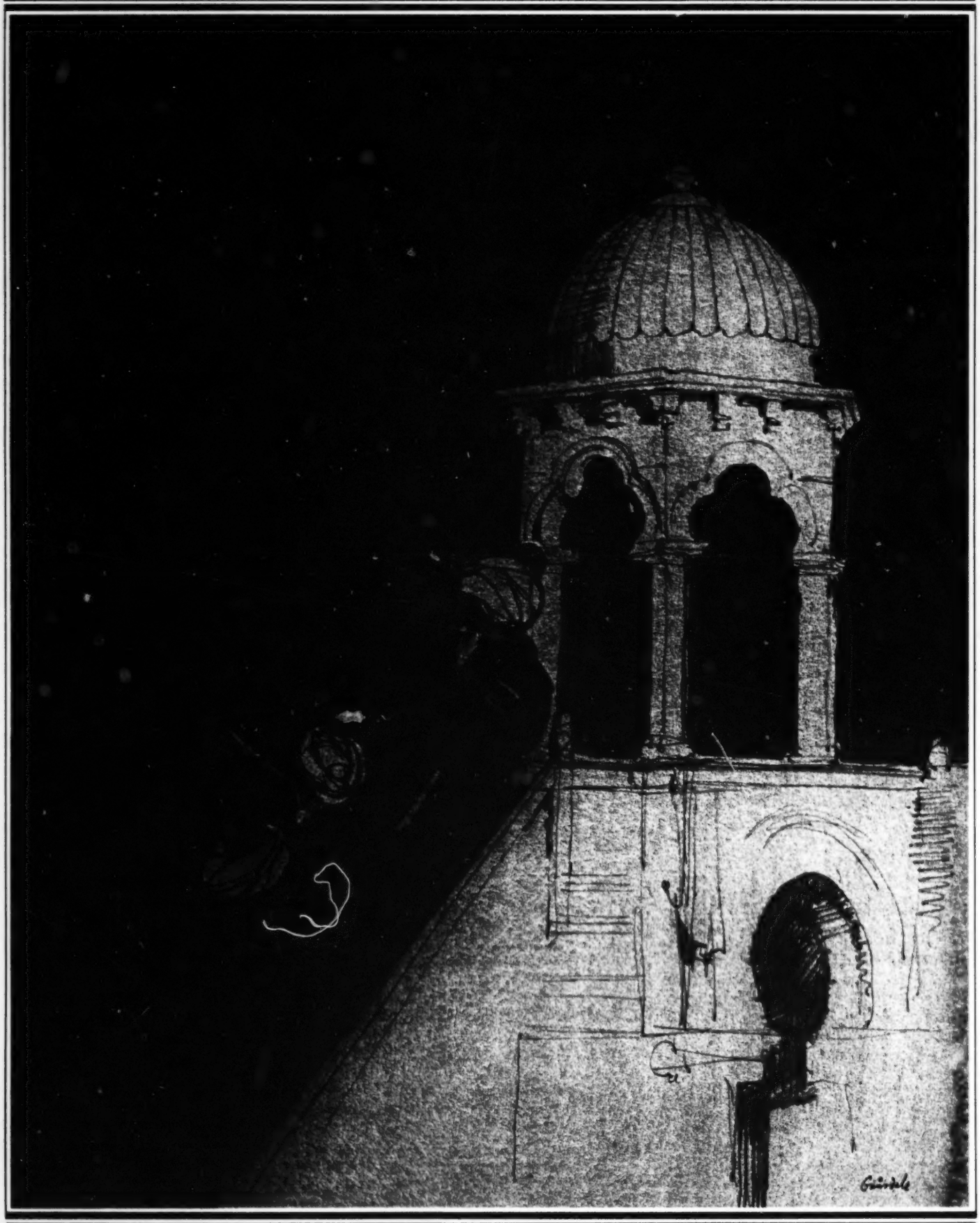
translation of Greek medical writings – particularly those by or attributed to Galen and Hippocrates – into Arabic. There then followed a period of original research by Muslim scientists, often leading to major revisions of the received tradition, and finally a period of codification in which the results of previous research were incorporated into convenient handbooks. Botany, particularly in so far as it was related to *materia medica*, received its first impetus from an illuminated copy of Dioscorides sent by the Byzantine emperor to the Abbasid court; this fundamental classical work was quickly rendered into Arabic, and many corrections and new plant identifications were added to it, particularly by scholars in North Africa and Muslim Spain. It was in Spain too that the first scientific works on agronomy were composed, works that are a prime source for our knowledge of medieval agricultural techniques in the Muslim world – techniques that were passed to Europe and greatly increased productivity.

Aristotle's work *Generation of Animals* was early translated into Arabic, and was made use of by al-Jahiz in his amusing *Book of Animals*, which includes a great deal of linguistic, literary and historical information in addition to passages of accurate, if amusing, scientific observation. Various handbooks of veterinary medicine were also composed, although these have so far received little attention from scholars.

Very few works of Greek science failed to find their way into Arabic during the Abbasid period. For one of the few times in human history, a culture with its own language, religion and customs embarked upon the extraordinary task of translating an alien intellectual tradition into its own language and fitting it into its own conceptual framework. In the process, old errors were corrected, and the experimental method, the basis of all scientific progress, was clearly enunciated. For one of the great achievements of medieval Muslim scientists was their willingness to correct the texts they transmitted. Just as they recomputed the circumference of the earth, and corrected the geographical information in Ptolemy on the basis of their own observations, so they dared question even Aristotle.

The works of Muslim scientists reached medieval Europe through Latin and Hebrew translations, for the most part made in Spain and somewhat later in Sicily. As early as the 10th century, astronomical works were being translated into Latin in Catalonia, and perhaps elsewhere in Spain. Later, during the 12th and 13th centuries, the works of Avicenna (Ibn Sina), Averroes (Ibn Rushd), Avempace (Ibn Bajja) and a host of others were translated into Latin and in the 13th century, at the court of Alfonso the Wise, into Spanish. At the very time that Baghdad fell to the Mongols, in 1258, and the Abbasid caliphate came to an end, scribes in Europe were preserving the Muslim scientific tradition. This is why, just as many Greek texts now survive only in Arabic dress, many Arabic scientific works only survive in Latin.

It is upon this tenuous and almost miraculous line of transmission that the scientific achievements of the modern world are based: the work of scholars of many different religious and linguistic backgrounds carefully transmitting, correcting and adding to a tradition that stretches back to Aristotle and beyond, each bound to his predecessor by a shared devotion to truth. ■



SCIENCE IN THE GOLDEN AGE

WRITTEN BY PAUL LUNDE. PAINTINGS BY MICHAEL GRIMSDALE.
ILLUSTRATIONS COURTESY THE BODLEIAN LIBRARY.

Towards the end of the 10th century, Ibn al-Nadim, son of a Baghdad bookseller and boon companion of Abbasid caliphs, compiled an annotated bibliography of books that had passed through his hands during the course of his long and active life. The sheer number of books that he lists, to say nothing of the range of their subject matter, is astonishing: Aristotle appears beside Sindbad the Sailor, Euclid beside the stories of Goha, Plato beside the poems of 'Antar ibn Shaddad.

The most striking feature of Ibn al-Nadim's catalog, however, is the number of books dealing with science. In a chapter entitled *The Reason Why Books on Philosophy and Other Ancient Sciences Became Plentiful in This Country,* Ibn al-Nadim relates a strange story of how Aristotle appeared in a dream to the Caliph al-Ma'mun and assured him that there was no conflict between reason and revelation. Thus reassured, al-Ma'mun set about obtaining the works of the Greek philosophers, the first step toward founding the famous House of Wisdom, a center for the translation of Greek scientific works into Arabic. Ibn al-Nadim told the story this way:

> This dream was one of the most definite reasons for the output of books. Between al-Ma'mun and the Byzantine emperor there was correspondence . . . so al-Ma'mun wrote to the Byzantine emperor asking his permission to obtain a selection of old scientific manuscripts, stored and treasured in the country of the Byzantines. After first refusing, he finally complied, and al-Ma'mun sent forth a number of scholars, among them al-Hajjaj ibn Matar, Ibn al-Batrik, Salman, the director of the House of Wisdom and many others. They selected books from those they found and brought them back to al-Ma'mun, who ordered them to prepare translations of them.

Though the House of Wisdom was founded in 830, Abbasid interest in Greek science had begun almost with the founding of the dynasty in 750 and by the time the House of Wisdom was launched, that interest had already been expressed in a number of important fields. The first Arabic translations of the medical works of Galen and Hippocrates, for example, were made by the official translator of the second Abbasid caliph, al-Mansur, builder of Baghdad. These sparked the interest in medicine so characteristic of Islam.

In 809, the Caliph Harun al-Rashid founded the first hospital in the Islamic World, and within a short time no major city in the empire was without one. The translator of these medical texts died in 800 – the year that Charlemagne was crowned Holy Roman Emperor. His son, Ibn al-Batrick, was among those scholars sent by al-Ma'mun to the Byzantine court in search of manuscripts.

But why should an Abbasid caliph, upholder of the Holy Law of Islam, dream of Aristotle, pagan philosopher to an alien race? Why did the Muslim community, engaged first in the great excitement of the conquests, and later in the difficult and absorbing task of administration, trouble with the science and philosophy of the Greeks, the lore of Persia and the mathematics of India?

The answers to these questions lie in the extraordinary cross-fertilization of once separate intellectual traditions that occurred as a result of the Muslim conquests of the seventh and early eighth centuries. These conquests united the ancient civilizations of the Middle East – to say nothing of North Africa and Spain – under a single rule for the first time since Alexander the Great, and Baghdad, from its foundation in 763, became a meeting place for Persians, Greeks, Indians, Copts, Berbers, Sogdians, Turks and even Chinese.

These people spoke many different languages, represented a great variety of cultures and an even wider variety of religions. Jews, Christians – of every possible variety – Manicheans, Hindus, Buddhists and even pagans jostled each other in the streets of the new capital. Yet the Abbasids, who tended to encourage talented men whatever their origin, absorbed them all and they, eager to contribute their talents helped to transform the empire.

The most single striking effect of the unification – of Anatolia, Iran, Syria, Iraq, Egypt, Palestine, North Africa and Spain – under Islamic rule was the opening of formerly closed frontiers – frontiers that had been closed politically, linguistically and intellectually since the death of Alexander the Great in the fourth century B.C. The Arabic word which we translate as "conquest" literally means "openings" – *futuh* — and this was indeed the effect of the Muslim conquests. For centuries the Byzantines had been at war with the Persians; now that major political and cultural frontier had fallen and students from the ancient university at Gondeshapur were able to meet colleagues from the philosophical schools of Alexandria in the streets of Baghdad and the effects were dramatic: no less than a scientific renaissance. It was rather as if Russia

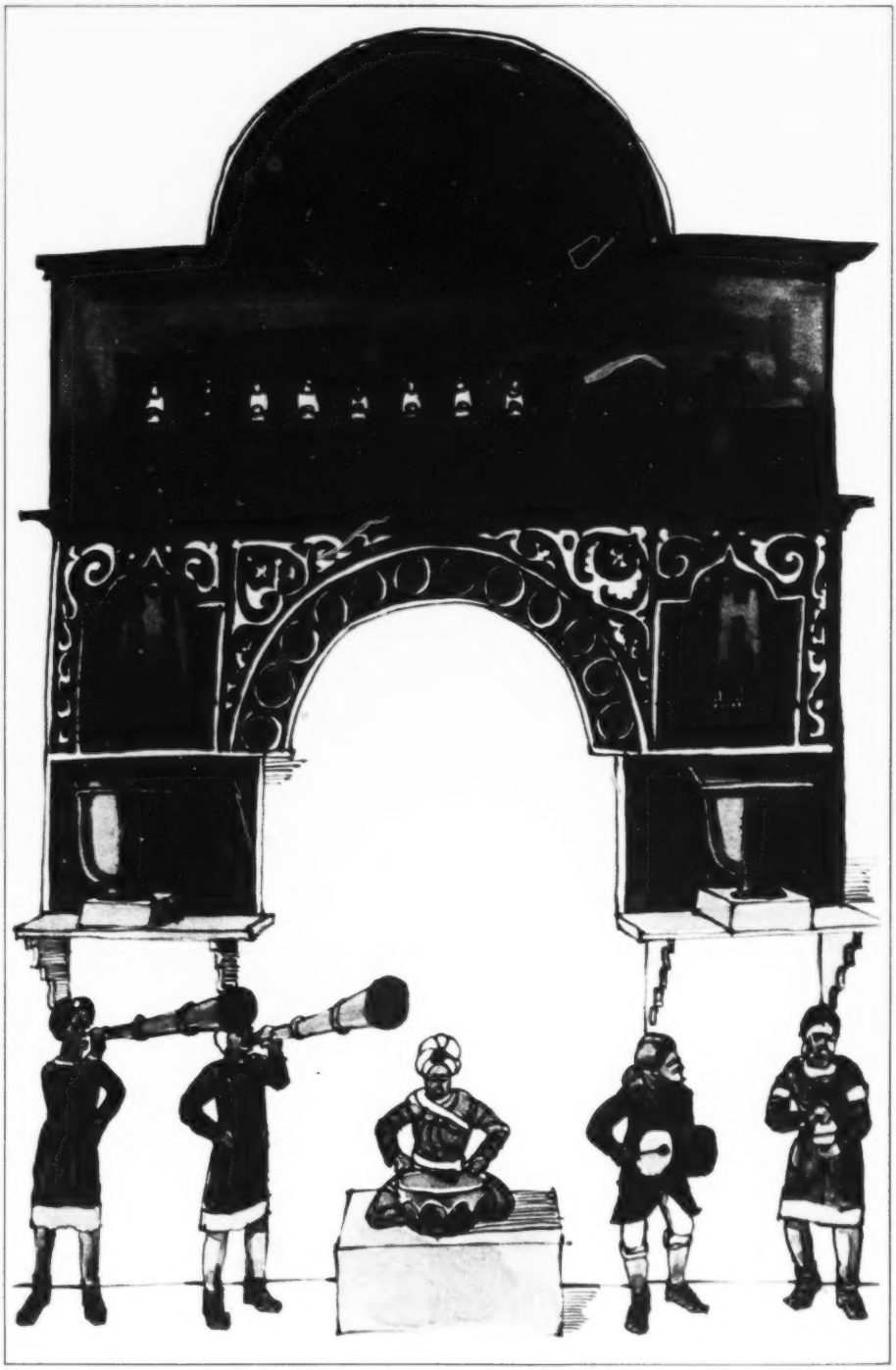
and America were to be united under the benevolent rule of a third party and able to freely exchange scientific information.

At first, contacts between scholars of such different backgrounds were limited – because of the lack of a common language. But by the time al-Ma'mun conceived the idea of the House of Wisdom, Arabic had already become the language of international scholarship as well as the language of Divine Revelation – and this was one of the most significant events in the history of ideas. Greek, long the language of philosophical and scientific inquiry, gave way to Arabic, and it was through the lens of Arabic that Western scholars, after the long half-light of the Dark Ages, first looked on the pages of Plato and Aristotle.

Another intellectual strand which was woven into the pattern of Islamic intellectual life during the early Abbasid period was that of Persia. The Abbasid movement had its origin in Khorasan, and particularly in the oasis of Marv (now in the Soviet Union), which had been the home of a medical school under the Sassanids. The Barmakid family, which supplied the Abbasid caliphs with their advisors and prime ministers from 750 until 803, was responsible for fostering translations from Pahlavi historical and scientific works into Arabic. It was through Pahlavi that the Arabs first came into contact with the learning of India, which had a long tradition of intellectual activity in the fields of astronomy, medicine and mathematics.

The Barmakids were also responsible for establishing the first paper mill in Baghdad.

Until the capture of Chinese paper makers by Muslim forces at the Battle of Talas in 751, precious books – such as the Koran – had been written on parchment, while papyrus was used for ephemeral government documents. Neither was very suitable, parchment because its price was prohibitive, papyrus because it decayed in the damper, colder climates outside its native home of Egypt. Paper, on the other hand, was the perfect writing material: cheap, long-lasting and attractive. This "invention" – for so it was – had an effect on education and scholarship as important as the invention of printing in the 15th century. Books were now within the reach of everyone, and soon schools were attached to most mosques, and libraries became common.



Unlike the Byzantines, with their suspicion of classical science and philosophy, the Muslims were actively enjoined by the Traditions – the *dicta* of the Prophet – to "seek learning, though it be in China." Another well-known Tradition states: "The search for knowledge is obligatory for every Muslim"; another that "The ink of scholars is worth more than the blood of martyrs."

In obedience to these injunctions, the first generations of Muslim scholars had devoted themselves to making the language of the Koran a vehicle for the expres-

sion of scientific ideas. Now, with the establishment of the House of Wisdom, with its library and staff of scholar-translators, the work could begin.

The job that lay before these men was Herculean. It was nothing less than the transfer of what had survived of the philosophical and scientific tradition of the ancient world – first into the Arabic language, and then into the conceptual framework of Islam. In the process, old errors were corrected and the experimental method, the basis of all scientific progress, was clearly enunciated.

According to a tradition which early Muslim scholars loved to quote, Aristotle had inscribed above the door of his house: "Let no one enter who does not have a knowledge of mathematics." This science, together with logic, its handmaiden, was seen as the basis of all others and al-Farabi, the great Arab philosopher, who died in 950, placed logic and mathematics near the head of his *Catalog of Sciences* – a book which in its Latin translation had a considerable influence upon the curricula of medieval European universities. He arranged the sciences as follows : (1) the linguistic sciences (2) logic (3) mathematics (4) physics (5) metaphysics (6) politics (7) jurisprudence and (8) theology.

Accordingly, al-Hajjaj ibn Yusuf ibn Matar, who accompanied the first embassy to the Byzantine court, brought back a copy of Euclid's *Elements* and made two translations, one for the Caliph Harun al-Rashid and the other for al-Ma'mun. These translations served as the basis for a critical edition prepared by two of the most famous translators associated with the House of Wisdom, Ishaq ibn Hunain and Thabit ibn Qurra. Muslim scholars also translated a commentary to Euclid by Hero of Alexandria, the third century B.C. inventor and mathematician, who developed a prototype of the steam engine.

This was not the only work on Euclid to find its way into Arabic. Translations were also prepared of works either by Euclid or attributed to him on the subjects of optics, music, ethics, logic and weights and measures. The foundations laid by these translations of Euclid were buttressed not only by the translation of Hero's commentaries, but by at least 11 major works by Archimedes, including a treatise on the construction of a water-clock. Nicho-

machus of Gerasa (Jerash) had written a book on number theory in the second century, heavily influenced by Pythagorean theories, and this provided the basis for some of the more arcane Islamic speculations in this field. Other late classical mathematicians, men like Theodosius of Tripoli, Apollonius of Perga, Theon and Menelaus were also translated into Syriac and/or Arabic by the staff of the House of Wisdom.

Armed with these translations, as well as certain Indian works, the great age of Islamic mathematical speculation began. Its early development was intimately linked with two other disciplines based upon it: astronomy and music, or the science of harmonics.

The first great advance on the inherited mathematical tradition was the introduction of Arabic numerals. Scholars working at the House of Wisdom first became aware of them in translations of Indian astronomical works, and hence called them "Indian." These numerals embodied the place-value theory which allowed numbers to be expressed by nine figures plus zero (Arabic *sifr*, "cipher") and not only simplified calculation of all sorts but made possible the development of algebra.

Muhammad ibn Musa al-Khwarizmi, born in the town now called Khiva, seems to have been the first to systematically explore their use in his book, *Addition and Subtraction in Indian Arithmetic*, later translated at Toledo into Latin under the title *Algorismi de numero indorum* and introduced as "Arabic numerals" into the West. Al-Khwarizmi used both Greek and Indian sources and their cross fertilization led to his famous *Kitab al-Jabr wa al-Muqabala*, the first book on algebra; the word "algebra" is derived from the second word in his title and originally meant "bone-setting." Al-Khwarizmi used it as a graphic description of one of the two operations he uses to solve quadratic equations.

Interest in geometry began with the translation, as we have seen, of Euclid's *Elements*. The Islamic world responded to geometry even more whole-heartedly than it had to algebra, as the beautifully drawn geometric proofs which adorn the pages of Arabic manuscripts on the subject attest. Its study influenced both architecture and the decorative arts and Ibn Khaldun recommended the study of geometry as good training in logical thought:

> Geometry is useful because it enlightens the intelligence of the man who cultivates it and gives him the habit of thinking exactly. Indeed, all the geometrical proofs are characterized by the clarity of their arrangement and by the evidence of their systematic order. That order and that arrangement make it impossible for any error to creep into the argument. Therefore the minds of people who are engaged in these studies are not in danger of being deceived and their intelligence is sharpened.

The great North African historian, in a striking and homely image, goes on to say that the study of mathematics in general "is like soap for the clothes, which washes away the dirt and cleans the spots and stains."

The men most responsible for encouraging the study of geometry were the sons of Musa ibn Shakir, al-Ma'mun's court astronomer. These three men – Muhammad, Ahmad and al-Hasan – devoted their lives and fortunes to the quest for knowledge. Their devotion to the cause of science is all the more remarkable by virtue of the fact that they were private citizens; their interest in these matters shows how widely the scientific renaissance of the ninth century reached. Ibn al-Nadim says of them:

> These men were some of those who took extreme pains to study the ancient sciences, for the sake of which they gave generously what was required, taxing themselves with fatigue. They dispatched to the Byzantine country men who sent scientific manuscripts back to them.

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They hired translators from various districts and kept them in attendance for many years, so that they brought to light wonders of learning. The sciences in which they were most interested were geometry, mechanics, dynamics, music and astronomy.

The "Banu Musa", or "Sons of Musa," as they were called, not only sponsored translations of Greek works, but wrote a series of important original studies of their own: The impressive title of one of their works by Muhammad Ibn Musa reads: *The Measurement of the Sphere, Trisection of the Angle, and Determination of Two Mean Proportionals to Form a Single Division Between Two Given Quantities.* His interests were not limited to geometry, however; he also wrote works on celestial mechanics, the atom, the origin of the earth, and an essay on the Ptolemaic universe. His brother Ahmad wrote a fundamental work on mechanics, while al-Hasan wrote a study of the geometrical properties of the elipse. Al-Hasan was perhaps the most gifted geometrician of his time. He translated the first six books of Euclid's *Elements* and is said not to have finished it because he was by then able to work out the remaining propositions himself.

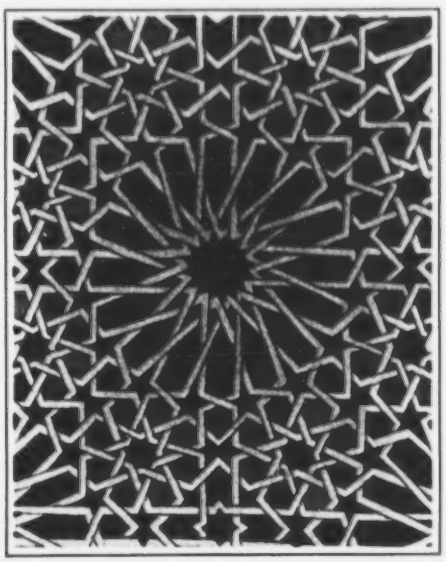
In terms of influence on mathematics in the West, the most important work of the Banu Musa was *On the Measurement of Plane and Spherical Figures,* which was translated in the 12th century by Gerard of Cremona under the title *Verba filiorum Moysi filii Sekir, id est Maumeti, Hameti, Hasan.*

The Banu Musa served a number of caliphs and occasionally were even involved in practical projects such as the construction of a canal. They were also famous for discovering perhaps the greatest of the scholars of the ninth century, Thabit ibn Qurra. While returning from a trip to Byzantium in search of manuscripts, Muhammad ibn Musa stopped in the town of Harran, where he met Thabit ibn Qurra, working as a money changer. Muhammad was so struck by Thabit's mastery of Syriac, Greek and Arabic that he persuaded Thabit to go to Baghdad – where such talents would find a suitable reward. There, Muhammad personally presented his *protégé* to the Caliph al-Mu'tadid, who was so struck in his turn by Thabit's learning and intelligence that he appointed him court astrologer.

To the small coterie of scholars at the House of Wisdom, Thabit was invaluable, if only because his knowledge of Greek and Syriac was unrivaled. This latter language was important, for in many cases the writings of the Greek scientists were either preserved in Syriac versions, made by Nestorian scholars of Iraq and Persia, or more frequently translated first into Syriac and then into Arabic. The reason for this was that the Christian communities, whose language was Syriac, tended to know Greek but not Arabic, while Muslim scholars found it easier to acquire a knowledge of Syriac, which is closely related to Arabic, than they did to learn Greek.

Most early translations prepared under the auspices of the House of Wisdom were done in this way, through the cooperation of teams of scholars of different religious and linguistic backgrounds. Thabit's success was due as much to his linguistic abilities in the three major languages as to his very great natural gifts.

Thabit immediately set about correcting some of the earlier translations of important works, such as Ishaq ibn Hunain's



editions of Ptolemy's *Almagest* and Euclid's *Elements.* His translations of key works by Archimedes, such as the famous *Measurement of the Circle,* were done into Latin in the 12th century by the indefatigable Gerard of Cremona, a worthy successor to Thabit.

Thabit also wrote more than 70 original works in the fields of mathematics, astronomy, astrology, ethics, mechanics, music, medicine, physics, philosophy and the construction of scientific instruments. He wrote valuable commentaries on Aristotle, Ptolemy and Euclid, as well as a series of introductions to other Greek thinkers.

Finally, his sons formed a dynasty of scholars that lasted to the end of the 10th century. His son Sinan was the most famous physician in Baghdad, director of several hospitals and court physician to three successive caliphs. He was an author as well, and wrote books on history, mathematics, astronomy and politics.

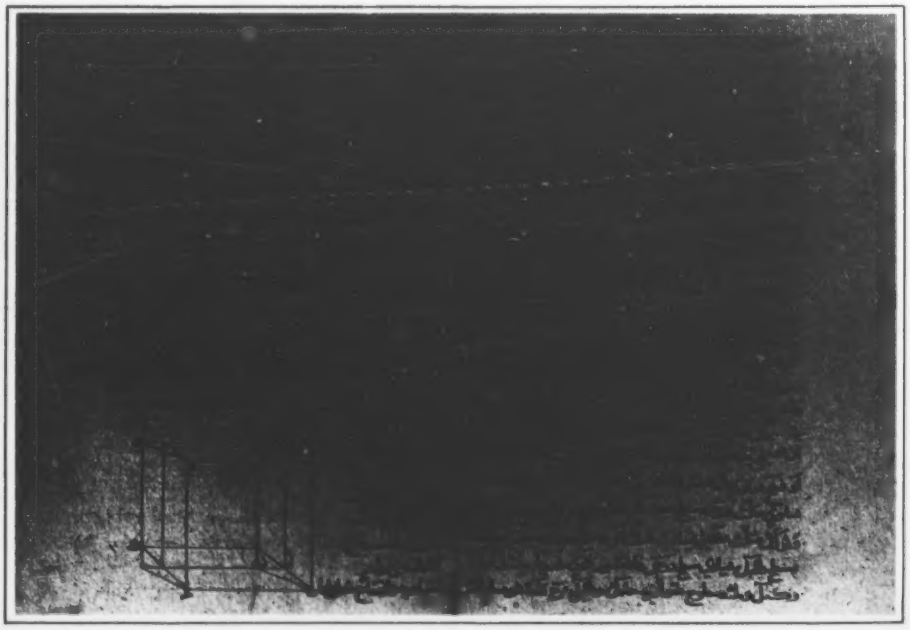
His son, Ibrahim ibn Sinan ibn Thabit, was also a prominent scientist, perhaps better known as an instrument maker. When Ibrahim was 17 years old, he first became interested in various ways of reckoning time by the sun, and wrote a systematic treatise on the construction of sundials which remained standard for many years. One of Ibrahim's brothers, Thabit, named after his grandfather, was director of various hospitals, as well as the author of a work on history.

Thabit ibn Qurra and his descendants, together with the Banu Musa, led lives of extraordinary dedication to science and were enormously productive. The effect of both their translations and their original works – on their own and succeeding generations of scholars – was pervasive.

The Banu Musa and Thabit ibn Qurra and his sons did not work in isolation. The works that issued from the House of Wisdom were the product of many different men – linguists, editors, researchers, scribes and technical advisors. We unfortunately know little about how the House of Wisdom was organized. But we do know that these scholars developed certain academic techniques, such as collating as many different manuscripts of a given work as possible in order to establish a critical text, glossaries, annotations written in the margin of the page and the compilation of dictionaries of technical terms. These techniques are still basic to all academic research. Ibn al-Nadim lists 57 translators who were associated with the House of Wisdom and says that the running costs of the organization, including maintenance, came to 500 gold dinars a month.

Two other men also played critical roles in the transmission of Greek learning to the Muslim world: Hunain ibn Ishaq – known to the Latin west as Joanitius – and Qusta ibn Luqa, from Baalbek.

Born near al-Hira, the old capital of the Lakhmid dynasty in Iraq, Hunain ibn Ishaq was the son of an apothecary, who, recog-



nizing his son's bent for medical studies, sent him to Baghdad. In the capital, Hunain found powerful supporters in the Banu Musa and set about learning Greek, and was soon translating the entire canon of Greek medical works into Arabic – including Galen, Hippocrates and the famous Hippocratic oath, obligatory then for Muslim physicians as it is everywhere today. Hunain was in many ways the most gifted of the translators associated with the House of Wisdom. His scholarly methods were impeccable, and he tended to translate more freely than many of the others, whose translations tended to err on the side of literalism – sometimes to the point of virtual incomprehensibility by those who did not know the original text.

Hunain also wrote at least 29 original treatises on medical topics. The most significant of these was a collection of 10 essays on ophthalmology. This work covers, in systematic fashion, the anatomy and physiology of the eye and the treatment of various diseases which afflict the vision. It is the first Arabic medical work to include anatomical drawings, and those that illustrate surviving manuscripts are very accurately drawn. This book was translated into Latin and for centuries remained the authoritative treatment of the subject in both Western and Eastern universities.

Hunain lived a life of exemplary piety and by his example did much to lend dignity to the medical profession. The Caliph al-Mutawakkil, seeking to test Hunain's integrity, ordered him to prepare a poison; "I have learned only the actions of beneficial drugs, confident that this is all that the Commander of the Faithful would want of me," replied Hunain, and was rewarded by being made the director of the House of Wisdom.

Qusta ibn Luqa was also an accomplished translator and scholar. Ibn al-Nadim, in fact, considered him an even better translator than Hunain, and says: "He was never subject to criticism, being a master of literary style in the Greek tongue and excelling also in Arabic diction." Qusta wrote some 40 original works on an intriguing variety of subjects: politics, medicine, "burning mirrors," insomnia, paralysis, diseases which affect the hair, fans, the cause of wind, an introduction to logic, a book of anecdotes about the Greek philosophers, dyes, nutrition, an introduction to geometry, astronomy and "The Bath," to mention only a few.

Yuhanna ibn Masawaih was one of the early directors of the House of Wisdom. He served under four caliphs – al-Ma'mun, al-Mu'tasim, al-Wathiq and al-Mutawakkil. He wrote almost exclusively about medical problems, in particular gynecology. Ibn al-Nadim related the following anecdote, which shows that the scholarly milieu of ninth century Baghdad was not unrelievedly serious:

> Ibn al-Hamdun, the court companion, made fun of Ibn Masawaih in the presence of al-Mutawakkil, whereupon Ibn Masawaih said to him, 'If in the place of your ignorance there were intelligence, it could be divided among a hundred black beetles so that each one of them would be more intelligent than Aristotle.'

Perhaps the greatest of the ninth century physicians was Abu Bakr Muhammad ibn Zakariya al-Razi, from the important Iranian town of Rayy. Al-Razi, known to the West as Rhazes, wrote, according to a bibliography of his writings compiled by al-Biruni in the 11th century, 184 works. Fifty-six of these dealt with medical topics. Al-Razi was deeply versed in the classical medical tradition, as it had been made accessible in the translations that poured forth from the House of Wisdom, but his originality lay in his open advocacy of experiment and observation.

The authority of the Greek philosophers and scientists was so great that lesser men were content to accept their views without question. Not al-Razi, who questioned everything, and relied more on his own observations than on received attitudes. His gigantic compendium called *al-Hawi*, "The All-Encompassing," contains al-Razi's daily observations and diagnoses. He wrote a very important work on smallpox and measles, in which he correctly differentiates their symptoms for the first time.

A friend of Ibn al-Nadim gave the following lively account of al-Razi at the height of his powers:

> When I questioned a man, one of the people of Rayy, of great age, about al-Razi, he said: 'He was an old man with a large sack-shaped head, who used to sit in his clinic with students around him...a patient would enter and describe his symptoms to the first persons who met him. If they had knowledge of what was wrong, good; but if they did not, he would pass from them to others. Then, if they hit upon the diagnosis, good; but if not, al-Razi himself would discuss the case. He was generous, distinguished and upright with the people. He was so kindly, compassionate with the poor and the sick that he used to bring them substantial rations and provide nursing for them...He was never found when not taking notes or transcribing them, whether to make a rough draft or a revised copy'.

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It is impossible to give an adequate idea of the range of al-Razi's thinking, even in the field of medicine (he was a philosopher and mathematician as well as a physician) but two titles give us a sense of the man's wit and common sense: *The Reason Why Some Persons and the Common People Leave a Physician Even if He Is Clever* and *A Clever Physician Does Not Have the Power to Heal All Diseases, For That Is Not Within The Realm of Possibility.*

Unlike their modern counterparts, these Muslim scholars did not specialize. They investigated any subject that interested them, for they regarded all fields of knowledge as essentially one. Perhaps the best illustration of this is al-Kindi, "The Philosopher of the Arabs," of whom Ibn al-Nadim says: "He was the most distinguished man of his time and unrivaled during his period for his knowledge of the ancient sciences as a whole."

Al-Kindi was the first Muslim philosopher to show that there was no essential conflict between Greek rationalism and Revelation. He was profoundly religious, and sought to use Aristotelian logic to support essential Islamic dogmas. But what is astonishing about al-Kindi is the range and depth of his speculations. He wrote about logic, philosophy, geometry, calculation, arithmetic, music, astronomy and a great many other things. He wrote an introduction to arithmetic as well as an almost endless list of important works: *The Use of Indian Arithmetic; That the Sphere Is the Largest of Bodily Forms and That the Circle is the Greatest of All Plane Shapes; That the Surface of the Sea is Spherical; Calculating the Azimuth on a Sphere; An Introduction to the Art of Music; Projection of Rays; An Explanation of the Cause of the Retrogression of the Stars; The Reason Why Rain Rarely Falls in Certain Places; Areas of Vaulted Chambers; How to Form a Circle Equal to the Surface of A Designated Cylinder; Determination of the Hours on a Hemisphere by Means of Geometry; The Cause of Vertigo; The Reason Why the Highest Part of the Sky is Cold, While the Part Near the Earth is Warm; The Reasons for Cloud Formations; Calculation and Making an Instrument to Determine the Distances of Heavenly Bodies, Crossbreeding the Dove, Species of the Bee* – and more.

Al-Kindi, and to a certain extent, al-Farabi, his successor, demonstrate the liveliness of Muslim thought as the 10th century drew to a close. Al-Farabi wrestled with many of the same philosophical problems as al-Kindi and wrote a book entitled *The Perfect City,* which expresses the degree to which Islam had first assimilated Greek ideas and then impressed them with its own indelible stamp. *The Perfect City* is an essay on what might be called ethical urbanism – the ideal city should be founded on moral and religious principles, and from there would flow the physical infrastructure. Al-Farabi undoubtedly had the magnificent round city of Baghdad, The City of Peace, in mind, which was consciously constructed on the pattern of the ancient cosmological cities of the east, its round form representing the Cosmos and its four gates the cardinal points of the compass.

With the death of al-Farabi in A.D. 950, the first period of Islamic scientific thought drew to a close. It had begun in 763 with the foundation of Baghdad; it had seen first the translation of the intellectual patrimony of the ancient world into Arabic, and then the first attempts to enlarge the intellectual horizons of that inheritance. Practically, the

same period witnessed the development of certain basic social institutions to a very high point – hospitals, universities, libraries, charitable institutions and public services, such as the post and water supply. During the next 300 years, although the political empire of the Abbasids would slowly fragment, the intellectual and scientific progress would continue, although now centered in provincial centers – particularly Khorasan and Spain.

A popular anecdote illustrates the intellectual background of the times. The inventor of the game of chess was granted a single request by the ruler to whom the game was first presented. The inventor's request was simple. He wanted as many grains of wheat as would result if one placed one grain on the first square of the board, two on the second, four on the third, eight on the fourth, and so on until the 64th square of the chess board. The ruler agreed to grant what seemed a modest request, but when he came to fulfill it, he discovered to his chagrin that the chess board would contain all the grain in the kingdom.

Al-Biruni, an 11th-century Persian scholar, wanted to know exactly how many grains of wheat were involved in this problem. He arrived at the figure 18,446,744,073,709,551,615, and anyone who thinks medieval computational methods primitive, should try to solve this problem without the use of a calculator.

Al-Biruni accompanied Mahmud of Ghazna's famous expedition against India in 1001. While there he learned Sanskrit and wrote a *History of India* based on native sources and his own observations. Al-Biruni's accuracy in determining the number of grains of wheat in the chessboard problem is reflected in his historical work. Like his predecessors in Baghdad, he reveals both wide-ranging interests and a concern with practical problems. For example, he is the first known writer to identify certain geologic facts, such as the formation of sedimentary rock. He was a great mathematical astronomer and was centuries ahead of his time in criticizing the Ptolemaic model of the universe.

Al-Biruni was also the author of a most detailed treatment of spherical trigonometry. Trigonometry is in fact an innovation of Muslim mathematicians, who were the first to clearly define the sine, cosine and cotangent functions. Other mathematicians, such as Nasir al-Din al-Tusi, also the author of an important work on ethics, greatly advanced mathematical theory in all branches, and 'Umar al-Khayyam, better known in the West as a poet, wrote the clearest and most elegant textbook of algebra ever produced.

Many of these advances took place as a spin-off of the consuming interest in astronomy so characteristic of Muslim lands at the time. Observatories were everywhere, and both physical and mathematical models of the universe were produced, and tables giving the distances of the fixed stars and the planets were continually refined. The size of the

earth was measured to a degree of accuracy not attained again until the present century. The Muslim world, however, never abandoned the earth-centered theory of the universe which it had inherited from the Greeks.

In physics, al-Biruni and his compatriot, 'Umar al-Khayyam, both wrote on the subject of specific gravity and developed formulae for determining both the specific and the absolute weight of any object. The interest in mirrors and lenses which had engaged some scholars associated with the House of Wisdom led to sophisticated theories of optics. Ibn al-Haitham, who wrote in the 10th century, was perhaps the greatest Muslim scientist to devote himself to optics. He was the author of the most important book on the subject, *The Book of Optics*, in which he gives a detailed treatment of the anatomy of the eye. He rejected the classical notion that rays issue from the eye, and correctly stated that instead the eye receives light from the object perceived.

The inventiveness of later Muslim thinkers was turned to practical fields such as agriculture and irrigation. Ibn al-Haitham had proposed a plan to dam the Nile as early as the 10th century, and although this project had to wait until the 20th century to be realized, other, less ambitious projects were common. Dams, reservoirs and acqueducts were constructed throughout the Islamic world and some of these systems survive to this day. Muslim engineers perfected the water wheel, and developed many different kinds, powered by man, animals, wind, river and tide.

Well-digging and the construction of the elaborate underground water systems called *qanat* required a high degree of engineering skill. Some of these *qanat* are as much as 15.5 meters (50 feet) deep and they were built with a very slight inclination over a long distance in order to tap underground water. They were provided with manholes so that they could be cleaned and repaired. By being placed underground they reduced water-loss through evaporation to a minimum.

Agriculture was dependent in much of the Middle East on irrigation, and a series of important books were written on soil analysis, water and what kinds of crops were suited to what soils. The passion for new plants, both for nutritive and medicinal purposes, led to widespread plant introductions: cotton, rice, mulberry trees, citrus fruits, cherries, all of which were adapted to new soils and climates in their spread from the East to the West. The technique of grafting was carried to a high art, particularly in North Africa and Spain.

Zoology and Botany were both actively cultivated sciences, and works like al-Damiri's *Lives of the Animals* contain much interesting material. In the field of botany, Abu Hanifa al-Dinawari, a 10th century scholar, made notable contributions.

Throughout the classical period of Islam, intellectual activity in every field was vigorous, first in Baghdad, later in Cairo and the regional capitals of Anatolia, Iran and, still later, in India. The Arabs accepted the classical heritage, fertilized it with the thought of India and the East and elaborated, criticized and corrected it; they then passed it on to the West where it formed the basis for the great technological achievements that have since transformed the world. ■

THE BOOK OF ANIMALS

WRITTEN BY PAUL LUNDE
ILLUSTRATIONS REPRODUCED COURTESY THE AMBROSIANA LIBRARY, MILAN

In every generation and among every nation, there are a few individuals with the desire to study the workings of nature; if they did not exist, those nations would perish," wrote Abu 'Uthman 'Amr ibn Bakr al-Kinani al-Fuqaimi al-Basri, better known as al-Jahiz – the Goggle-Eyed – in his magnum opus, the *Book of Animals*.

Al-Jahiz himself was one of those individuals. He lived, furthermore, during one of the most exciting epochs of intellectual history – the period of the transmission of Greek science to the Arabs and the development of Arabic prose literature – and was intimately involved in both.

Born about the year 776, some 14 years after the foundation of Baghdad by the Abbasid Caliph al-Mansur, al-Jahiz grew up in Basra, founded early in Islamic times as a garrison city, but now, along with its rival city, Kufa, a major intellectual center.

Basra contributed substantially to al-Jahiz's intellectual development. It was there that he first went to school – studying under some of the most eminent scholars of Islam. Even after he migrated to Baghdad – attracted by the greater scope of the capital – he never lost his affection for his home; after some 50 years in Baghdad, he returned to Basra, and it was there that he died. According to legend he was crushed to death by a collapsing pile of books in the year 868.

Legendary though it may be, that story illustrates an important fact about the world in which al-Jahiz lived: books were accessible. Though paper had been introduced into the Islamic world only shortly before al-Jahiz's birth, it had, by the time he was in his 30s, virtually replaced parchment.

The availability of a cheap writing material was accompanied by another social phenomenon, of which al-Jahiz himself was a product: the rise of a reading public. For the first time since the fall of the Roman Empire, the cities of the Middle East contained a large number of literate people – many of humble origins.

Al-Jahiz and his parents, for example, were poor themselves; as a young man of 20 he seems to have sold fish along one of

the Basran canals. Nevertheless, al-Jahiz learned to read and write at an early age, indicating the opportunities for what today's sociologists would call "upward mobility" in eighth-century Iraq. Al-Jahiz tells the story of how his mother presented him with a tray of paper notebooks, and told him that it would be by means of these that he would earn his living.

Al-Jahiz began his career as a writer – then, as now, a precarious profession – while still in Basra. He wrote an essay on the institution of the caliphate – which met with approval at the court in Baghdad – and from then on seems to have supported himself entirely by his pen, if we except a single three-day stint as a government clerk. The fact that he never held an official position allowed him an intellectual freedom impossible to someone connected to the court – though he did dedicate a number of his works to viziers and other powerful functionaries, and received 5,000 gold dinars from the official to whom he dedicated his *Book of Animals*.

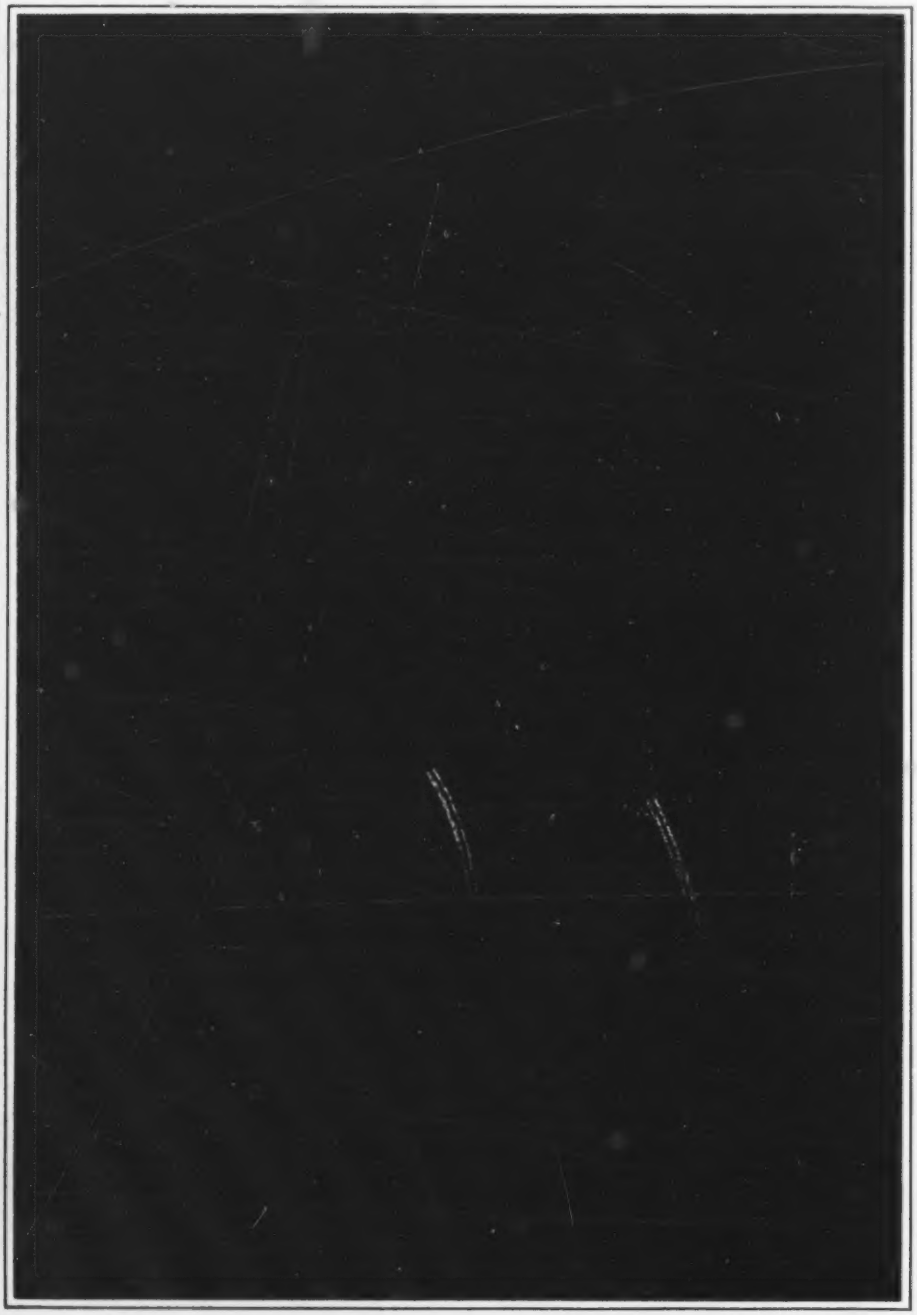
During his long lifetime – he lived until he was 92 – al-Jahiz composed some 200 works, of varying length, on an extraordinary range of topics. Of these, only 30 or so survive today – enough nevertheless to show the omnivorous curiosity of the author. Al-Jahiz wrote *Levity and Seriousness, The Art of Keeping One's Mouth Shut, Misers, Early Arab Food, In Praise of Merchants, Against Civil Servants, The Squaring of the Circle, The Merits of the Turks*, and, perhaps the most important, the *Book of Animals*.

The titles, however, give only a faint idea of their contents. Incapable of keeping to the point, al-Jahiz's essays wander from anecdote to anecdote, digression to digression, until both he and the reader lose sight of the original subject entirely.

Despite his propensity to meander in prose, al-Jahiz was particularly interested in style and correct expression. "The best style," he says in an essay on schoolteachers, "is the clearest, the style that

needs no explication and no notes, that conforms to the subject expressed, neither exceeding it nor falling short."

This interest in style was characteristic of a group of Basran scholars, who, during the late eighth and early ninth centuries, sought to preserve the linguistic heritage of the Arabs by recording the poetry and sayings of the Bedouin of the Arabian peninsula. This movement had unanticipated results: because of their almost anthropological interest in the language and customs of the Bedouin, and in the social conditions of Arabia during both the pre-Islamic and Islamic periods, the Basran scholars achieved a deep appreciation of Arabic grammar and pre-Islamic poetry. They went on to compose sophisticated commentaries on the Koran, critical editions of poetry and treatises on grammar, and to compile dictionaries and specialized word-lists.



A master of these disciplines, al-Jahiz was one of the first writers of Arabic to work all the diverse preoccupations of the Basran scholarly milieu – grammar, prophetic tradition, rhetoric, lexicography and poetry – into a "literature" – that is, prose compositions to be read by non-specialists for pleasure and instruction.

Around the year 815, only two years after the founding of the House of Wisdom, al-Jahiz moved to Baghdad, where he was exposed to a new and important influence: Greek science, particularly Aristotelian thought. Attracted by scholastic theology, for instance, he subsequently used the dialectic method of the theologians in many of his works, often with humorous intent.

For al-Jahiz never lost sight of his readers, and developed a very personal and characteristic style, which blended anecdote, serious subjects and jokes, in an effort to hold their interest. He described his style himself, saying:

> My books contain above all unusual anecdotes, wise and beautifully expressed sayings handed down by the Companions of the Prophet, sayings which will lead to the acquisition of good qualities and the performance of good works ... they also contain stories of the conduct of kings and caliphs and their ministers and courtiers, and the most interesting events of their lives.

In Baghdad, al-Jahiz not only fused the Islamic sciences to Greek rationalism, but created Arabic prose literature. He showed that Arabic was flexible enough to handle any subject with ease, and although he was not personally associated with the House of Wisdom, his linguistic achievement paralleled – indeed surpassed – the efforts of the scholars engaged in rendering Greek scientific texts into Arabic.

His works attest the remarkable spread of Greek ideas among ordinary readers. Both in his subject matter and vocabulary, he presumes a familiarity – albeit superficial – with Aristotle and the technical terminology of scholastic theology. He tells many anecdotes of the scholars of the House of Wisdom, many of whom appear to have been his friends.

The book that best illustrates his method is his *Book of Animals – Kitab al-Hayawan* – which, even incomplete, runs to seven fat volumes in the printed edition.

Despite the title, the *Book of Animals* is by no means conventional zoology, or even a conventional bestiary. It is an enormous collection of lore about animals – including insects – culled from the Koran, the Traditions, pre-Islamic poetry, proverbs, storytellers, sailors, personal observation and Aristotle's *Generation of Animals*.

But this is by no means all. In keeping with his theories of planned disorder, he introduces anecdotes of famous men, snippets of history, anthropology, etymology and jokes. The bewildering variety of its contents, in fact, has always daunted translators, and later natural historians. Al-Damiri, who lived in the 14th century and wrote a well-known encyclopedia called *The Lives of the Animals*, used much of the scientific and linguistic information from al-Jahiz, but eliminated the anecdotes, poetry, digressions and jokes.

The "literary" quality of the *Book of Animals*, however, should not obscure the fact that it contains scientific information of great value. Anticipating a number of concepts which were not to be fully developed until the time of Darwin and his successors, al-Jahiz toys with evolutionary theory, discusses animal mimicry – noting that certain parasites adapt to the color of their host – and writes at length on the influences of climate and diet on men, plants and animals of different geographical regions. He even gets into animal communication, psychology and the degree of intelligence of insect and animal species. He gives a detailed account of the social organization of ants, including, from his own observation, a description of how they store grain in their nests in such a way that it does not spoil during the rainy season. He knows that some insects are responsive to light – and uses this information to suggest a clever way of ridding a room of mosquitoes and flies.

His greatest service, perhaps, was in popularizing science and the rational method, and in showing that a literary man could concern himself with any subject.

A devout Muslim, al-Jahiz regarded the physical world as the visible sign of God's will. His purpose in writing the *Book of Animals* was not merely to entertain, but to lead his readers to an appreciation of the wonders of God's creation, which he believed to be as manifest in the most insignificant as in the grandest:

> I would have you know that a pebble proves the existence of God just as much as a mountain, and the human body is evidence as strong as the universe that contains our world: for this purpose the small and slight carries as much weight as the great and vast.

Sadly, few works of al-Jahiz have survived the vicissitudes of time, but those that have make us regret all the more the ones that have been lost. Together they present a faithful and lively portrait of Baghdad and Basra during the Golden Age of Islam. He writes of singing girls, vagabonds, scholars, theologians, caliphs and viziers, and a very detailed picture of everyday life in

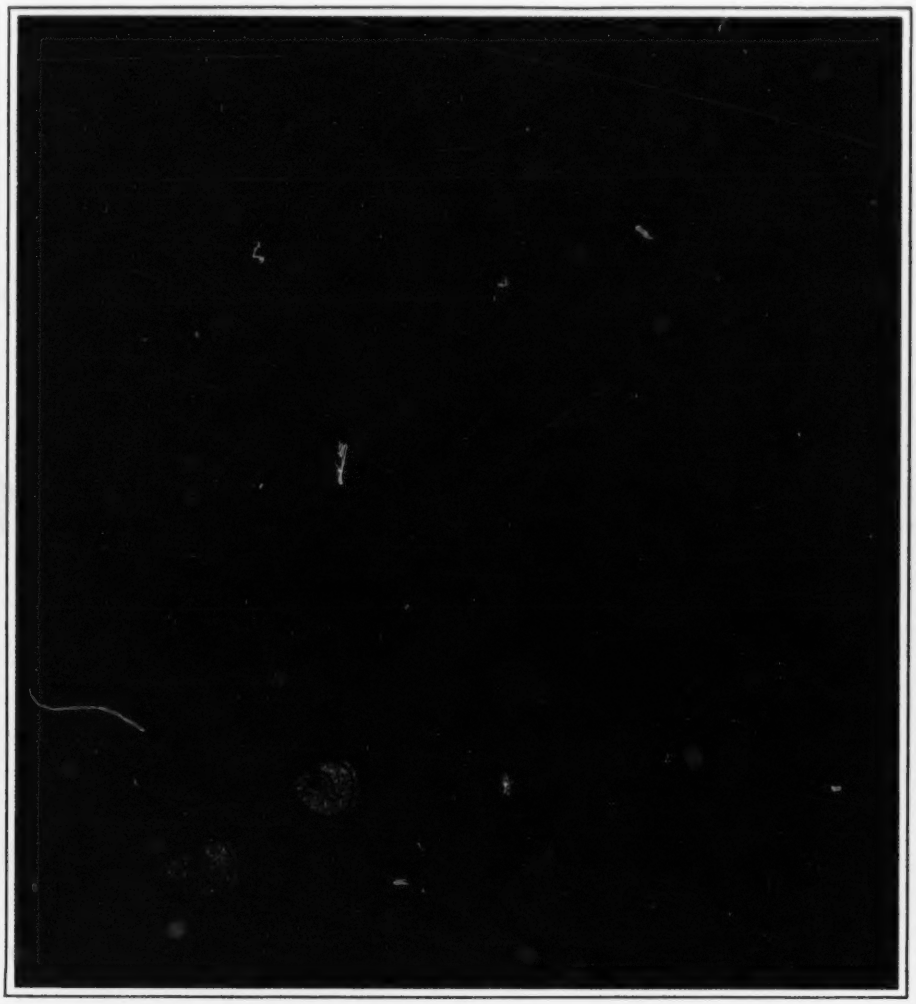
ninth-century Iraq could be extracted from his works. More importantly, he communicates to us the excitement of an intelligent non-specialist confronted with radical scientific, philosophical and theological speculations. Baghdad and Basra were awhirl with ideas, and al-Jahiz is very funny about the pretensions of people who studded their conversation with technical terms like "atom" without in the least understanding what an atom was.

At the same time, al-Jahiz enthusiastically supported certain aspects of the Greek tradition, by which he meant primarily Aristotle. He believed in the scientific method – as it was then understood – and applied reason and logic to observed phenomena. Loving a good story, however, al-Jahiz could never resist passing on the most preposterous yarns of sailors and Bedouin.

This lack of rational plan, so much a feature of his works, may have been at least partly deliberate, since his greatest fear was boring his readers. This does not mean that he was never serious, but that in all his major works, seriousness and humor are inextricably mixed; it is sometimes difficult to know when he is joking and when he is not. It is also difficult to pin al-Jahiz down on a given topic, for he loved to present debates between two social classes – scholars and merchants, mules and horses for instance – in which the merits of each are paraded before the reader. What the author himself thought is often not obvious, and it is possible that in these dialogues he was primarily interested in showing his skill at taking both sides of an argument.

He had a great love of books, and his *Book of Animals* begins with a long passage in their praise. It would have saddened him that so many of his own have perished, but he would have been delighted, one feels, with the manuscript from which the illustrations that adorn this article are taken.

This manuscript, which dates from the 14th century, was discovered in the Ambrosiana Library in Milan in 1939 by the Swedish scholar Oscar Löfgren. Löfgren stumbled on it, for it was not listed in the catalog of the manuscripts in the Ambrosiana done by von Hammer in 1839. He identified the text as a fragment of the *Book of Animals* – 87 folios containing about one-tenth of the complete text. The manuscript is not only fragmentary, but disordered. An ownership mark on the last folio states that when the fragment passed into the hands of a certain 'Abd al-Rahman al-Maghribi in 1615, it had 94 folios, so even at that date the manuscript was incomplete. It is not known how or when the Ambrosiana Library obtained the manuscript.



The Ambrosiana manuscript is textually very important. It is obviously copied by an educated scribe who has indicated the vowels – not normally written in Arabic – which allow the text to be more accurately understood than heretofore. This is doubly important as few manuscripts of the *Book of Animals* survive, and the Ambrosiana manuscript is among the earliest of those that do.

Even more important than the text, however, are the superb miniatures which illuminate it. Illustrated Arabic manuscripts of any sort are extremely rare, and this is the only illustrated copy of a work by al-Jahiz in existence. The 30 miniatures, done in a deliberately archaizing style – perhaps imitated from an earlier illustrated manuscript from al-Jahiz's native Iraq – were done at the high point of Arabic manuscript illumination: 14th-century Mamluk Egypt. A recent exhibition of Mamluk art at the Freer Gallery in Washington D.C. (see *Aramco World*, November-December 1981) has familiarized the American public with the glories of the Islamic decorative arts under the Mamluk dynasty. The style of the miniatures, consciously old-fashioned, succeeds in capturing the mood of al-Jahiz's prose – they are lively, highly colored and gently humorous. One cannot help feeling that al-Jahiz would have liked them, especially in view of his own admiration for the pictorial arts of the Byzantines and the Chinese – which he mentions in the *Book of Animals*. ■

SCIENCE IN AL-ANDALUS

WRITTEN BY PAUL LUNDE. PAINTINGS BY MICHAEL GRIMSDALE.
ILLUSTRATIONS COURTESY THE BODLEIAN LIBRARY. PHOTOGRAPH BY TOR EIGELAND

The medieval Christians of Spain had a legend that Roderick, the last King of the Visigoths, was responsible for unleashing the Arab invasion of the Iberian Peninsula because, in defiance of his plighted word, he unlocked the gates of an enchanted palace he had sworn not to tamper with.

As far as the West was concerned, the Arab invasion *did* unlock an enchanted palace. Following the collapse of the Roman Empire, Vandals, Huns and Visigoths had pillaged and burned their way through the Iberian Peninsula, establishing ephemeral kingdoms which lasted only as long as loot poured in, and were then destroyed in their turn. Then, without warning, in the year 711, came the Arabs – to settle, fall in love with the land and create the first civilization Europe had known since the Roman legions had given up the unequal fight against the barbarian hordes.

Spain first prospered under the rule of the Umayyads, who established a dynasty there after they had lost the caliphate in the east to the Abbasids. At first, the culture of the Umayyad court at Cordoba was wholly derivative. Fashions, both in literature and dress, were imitative of those current in the Abbasids' newly founded capital of Baghdad. Scholars from the more sophisticated lands to the east were always assured of a warm reception at the court of Cordoba, where their colleagues would listen avidly for news of what was being discussed in the capital, what people were wearing, what songs were being sung, and – above all – what books were being read.

For Islamic culture was pre-eminently a culture of the book. The introduction of paper from China in 751 gave an impetus to learning and an excitement for ideas which the world had never before known. Books became more available than they had been even in Rome, and incomparably cheaper than they were in the Latin West, where they continued to be written on expensive parchment. In the 12th century, a man sold 120 acres of land in order to buy a single Book of Hours. In the ninth century, the library of the monastery of St. Gall was the largest in Europe. It boasted 36 volumes. At the same time, that of Cordoba contained 500,000. The cultural lag between East and West in the Middle Ages can be attributed partly to the fact that the Arabs had paper, while the Latin West did not.

It took much more than paper to create an intellectual and scientific culture like

that of Islamic Spain, of course. Islam, with its tolerance and encouragement of both secular and religious learning, created the necessary climate for the exchange of ideas. The court of Cordoba, like that of Baghdad, was open to Muslims, Jews and Christians alike, and one prominent bishop complained that young Christian men were devoting themselves to the study of Arabic, rather than to Latin – a reflection of the fact that Arabic, in a surprisingly short time, had become the international language of science, as English has today.

Islamic culture in Spain began to flourish in earnest during the reign of 'Abd al-Rahman II of Cordoba – as Arabic spread increasingly among his non-Muslim subjects, especially in the cities, and led to a great flowering of intellectual activity of all kinds.

In a courtly society, the tastes and predilections of the ruler set the tone for society at large, and 'Abd al-Rahman II, passionately interested in both the religious and the secular sciences, was determined to show the world that his court was in no way inferior to the court of the Caliphs at Baghdad. To this end, therefore, he actively recruited scholars by offering handsome inducements to overcome their initial reluctance to live in what many from the lands in the East considered the provinces. As a result, many scholars, poets, philosophers, historians and musicians migrated to al-Andalus, and established the basis of the intellectual tradition and educational system which made Spain so outstanding for the next 400 years.

Another result was that an infrastructure of libraries – both public and private – mosques, hospitals, and research institutions rapidly grew up and famous scholars in the East, hearing of these amenities, flocked to the West. They in turn attracted students of their own; in the Islamic world it was not at all unusual for a student to travel thousands of miles to study at the feet of a famous professor.

Science : The Islamic Legacy

One of the earliest of these scholars was 'Abbas ibn Firnas, who died in the year A.D. 888 and who, had he lived in the Florence of the Medici, would have been a "Renaissance Man." He came to Cordoba to teach music, then a branch of mathematical theory, but – not a man to limit himself to a single field of study – soon became interested in the mechanics of flight. He constructed a pair of wings, made out of feathers in a wooden frame, and attempted to fly – anticipating Leonardo da Vinci by some 600 years.

Luckily, 'Abbas survived, and, undiscouraged, turned his mind to the construction of a planetarium in which the planets actually revolved – it would be extremely interesting to know the details of the gearing mechanism. It also simulated such celestial phenomena as thunder and lightning and was, of course, a wild success. Next 'Abbas turned to the mathematical problems involved in the regularity of the facets of certain crystals and evolved a formula for manufacturing artificial crystals.

It must be remembered that a knowledge of the achievements of men like 'Abbas has come to us purely by chance. It has been estimated that today there are 250,000 Arabic manuscripts in Western and Eastern libraries, including private collections. Yet in the 10th century, private libraries existed which contained as many as 500,000 books. Literally millions of books must have perished, and with them the achievements of a great many scholars and scientists, whose books, had they survived, might have changed the course of history. As it is, even now, only a tiny proportion of existing Arabic scientific texts have been studied, and it will take years to form a more exact idea of the contributions of Muslim scientists to the history of ideas.

One of the fields most assiduously cultivated in Spain was natural science. Although Andalusian scholars did not make contributions as fundamental as those made by their colleagues in the East, those that they did make had more effect on the later development of science and technology, for it was through Spain and the scholars of al-Andalus that these ideas reached the West.

No school of translators comparable to the House of Wisdom of al-Ma'mun existed in Spain, and Andalusian scholars seem not to have interested themselves in the natural sciences until the translations of the House of Wisdom reached them.

Interest in mathematics, astronomy, and medicine was always lively, because of their obvious utility – mathematics for commercial purposes, computation of the rather complicated Islamic laws of inheritance, and as a basis for measuring distances. Astronomy was useful for determining the times of prayer and adjusting the calendar, and the study of medicine needed no apology. The introduction of the new Aristotelian ideas, however, even in Arab dress, aroused a certain amount of suspicion in the conservative West, and it was some time before public opinion would accept that Aristotelian logic did not conflict with the Revelation.

Part of the suspicion with which certain of the ideas emanating from the scholars of the Abbasid court were viewed was due to an inadequate distinction between sciences and pseudo-sciences. This was a distinction which the Muslims made at a much earlier date than Western scholars, who, even during the Renaissance, tended to confound astronomy with astrology, chemistry with alchemy. Ibn Hazm, a leading Andalusian scholar of the 11th century and staunchly conservative, was very outspoken on this point. People who advocated the efficacy of talismans, magic, alchemy, and astrology he calls shameless liars. This rational approach did much to make Islam preeminent in the natural sciences.

The study of mathematics and astronomy went hand in hand. Al-Khwarizmi's famous book entitled *The Calculation of Integration and Equation* reached al-Andalus at an early date, and became the foundation of much later speculation. In it, Al-Khwarizmi dealt with equations, algebraic multiplication and division, measurement of surfaces, and other questions. Al-Khwarizmi was the first to introduce the use of what he called "Indian" and what we call "Arabic" numerals. The exact method of the transmission of these numerals – and the place-value idea which they embodied – is not known, but the symbols used to represent the numbers had slightly different forms in Eastern and Western Islam, and the forms of our numerals are derived from those used in al-Andalus. The work of al-Khwarizmi, which now only survives in a 12th century Latin translation made in Spain, together with a translation of Euclid's *Elements*, became the two foundations of subsequent mathematical developments in al-Andalus.

The first original mathematician and astronomer of al-Andalus was the 10th century's Mas'lama al-Majriti. He had been preceded by competent scientists – men like Ibn Abi 'Ubaida of Valencia, who in the ninth century was a leading astronomer – and the *emigré* from Baghdad, Ibn Taimiyyah, who was both a well-known physician and an astronomer, but al-Majriti was in a class by himself. He wrote a number of works on mathematics and astronomy, studied and elaborated the Arabic translation of Ptolemy's *Almagest* and enlarged and corrected the astronomical tables of al-Khwarizmi himself. He compiled conversion tables, in which the dates of the Persian calendar were related to *Hijra* dates, so that for the first time the events of Persia's past could be dated with precision.

Al-Zarqali, known to the Latin West as Arzachel, was another leading mathematician and astronomer who flourished in Cordoba in the 11th century. He combined theoretical knowledge with technical skill, and excelled at the construction of precision instruments for astronomical use. He built a waterclock capable of determining the hours of the day and night and indicating the days of the lunar month. He contributed to the compilation of the famous *Toledan Tables*, a highly accurate compilation of astronomical data. His *Book of Tables*, written in the form of an almanac (almanac is an Arabic word meaning climate, originally indicating the stations of the moon) contains tables which allow one to find on what day the Coptic, Roman, lunar and Persian months begin; others give the position of the various planets at any given time; and still others allow prediction of solar and lunar eclipses. He also compiled valuable tables of latitude and longitude; many of his works were translated, both into Spanish and into Latin.

Still another luminary was al-Bitruji (the Latin scholars of the middle ages called him Alpetragius), who developed a new theory of stellar movement and wrote the *Book of Form* in which it is detailed.

The influence of these astronomical works was immense. Today, for example, the very appelations of the constellations still bear the names given them by Muslim astronomers – Acrab (from *'aqrab*, "scorp-

ion"), Altair (from *al-ta'ir*, "the flyer"), Deneb (from *dhanb*, "tail"), Pherkard (from *farqad*, "calf") – and words such as zenith nadir and azimuth, all still in use today, recall the works of the Muslim scholars of al-Andalus.

But the Muslim science *par excellence* was the study of medicine. Interest in medicine goes back to the very earliest times. The Prophet himself stated that there was a remedy for every illness, and was aware that some diseases were contagious.

The great contribution of the Arabs was to put the study of medicine on a scientific footing, and eliminate superstition and harmful folk-practices. Medicine was considered a highly technical calling, and one which required long study and training. Elaborate codes were formulated to regulate the professional conduct of doctors. It was not enough to have a mastery of one's subject in order to practice medicine. Certain moral qualities were mandatory. Ibn Hazm said that a doctor should be kind, understanding, friendly, good, able to endure insults and adverse criticism; he must keep his hair short, and his fingernails as well; he must wear clean, white clothes, and behave with dignity.

Before doctors could practice, they had to pass an examination, and if they passed they had to take the Hippocratic oath, which, if neglected, could lead to dismissal.

Hospitals were similarly organized. The large one built in Cordoba was provided with running water and baths, had different sections for the treatment of various diseases, each section of which was headed by a specialist. Hospitals were required to be open 24 hours a day to handle emergency cases, and could not turn any patient away.

Muslim physicians made many important additions to the body of medical knowledge which they inherited from the Greeks. Ibn al-Nafis, for example, discovered the lesser circulation of the blood hundreds of years before Harvey and ideas of quarantine sprang from an empirical notion of contagion.

Another example is Ibn Juljul who was born in Cordoba in 943, became a leading physician by the age of 24 (he began his studies of medicine at the age of 14) and compiled a commentary on the *De Materia Medica* of Dioscorides, and a special treatise on drugs found in al-Andalus. In his *Categories of Physicians*, composed at the request of one of the Umayyad princes, he also presents a history of the medical profession from the time of Aesculapius to his own day.

During the 10th century, al-Andalus produced a large number of excellent physicians. Several went to Baghdad, where they studied Greek medical works under the famous translators Thabit Ibn Qurra and Thabit ibn Sinan. On their return, they were lodged in the government complex at Madinat al-Zahra. One of these men, Ahmad ibn Harran, was placed in charge of a dispensary which provided free medical care and food to poor patients.

Ibn Shuhaid, also known as a popular doctor, wrote a fundamental work on the use of drugs. He – like many of his contemporaries – recommended drugs only if the patient did not respond to diet, and said that if they must be used, simple drugs should be employed in all cases but the most serious.

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Al-Zahrawi, who died in 1013, was the most famous surgeon of the Middle Ages. He was court physician of al-Hakam II, and his great work, the *Tasrif*, was translated into Latin by Gerard of Cremona and became a leading medical text in European universities in the later middle ages. The section on surgery contains a number of illustrations of surgical instruments of elegant, functional design and great precision. It describes lithotrites, amputations, ophthalmic and dental surgery, the treatment of wounds and fractures.

Ibn Zuhr, known as Avenzoar who died in 1162, was born in Seville and earned a great reputation throughout North Africa and Spain. He described abscesses and mediastinal tumors for the first time, and made original experiments in therapeutics. One of his works, the *Taysir*, was translated into Latin in 1280 and became a standard work.

An outgrowth of the interest in medicine was the study of botany. The most famous Andalusian botanist was Ibn Baitar, who wrote a famous book called *Collection of Simple Drugs and Food*. It is an alphabetically arranged compendium of medicinal plants of all sorts, most of which were native to Spain and North Africa, which he spent a lifetime gathering. Where possible, he gives the Berber, Arabic, and sometimes Romance names of the plant, so that for linguists his work is of special interest. In each article, he gives information about the preparation of the drug and its administration, purpose and dosage.

The last of the great Andalusian physicians was Ibn al-Khatib, who was also a noted historian, poet, and statesman. Among his other works, he wrote an important work on the theory of contagion: "The fact of infection becomes clear to the investigator who notices how he who establishes contact with the afflicted gets the disease, whereas he who is not in contact remains safe, and how transmitting is effected through garments, vessels, and earrings."

Ibn al-Khatib was the last representative of the Andalusian medical tradition. Soon after his death, the energies of the Muslims of al-Andalus were wholly absorbed in the long costly struggle against the Christian *reconquista*.

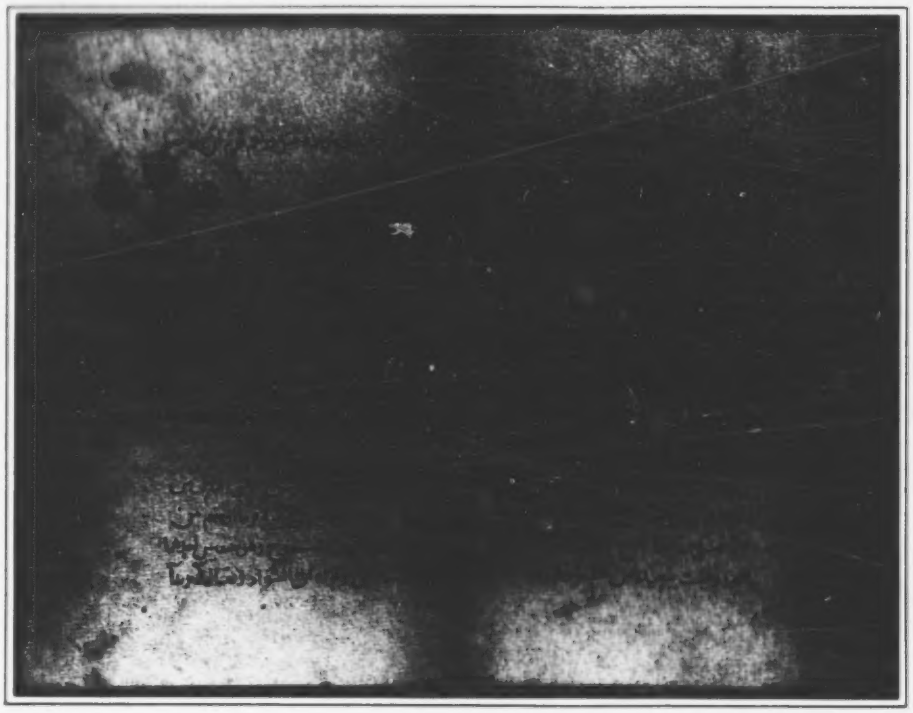
Another field that interested the scholars of al-Andalus was the study of geography and many of the finest Muslim works in this field were produced there. Economic and political considerations played some part in the development of the study of geography, but it was above all their all-consuming curiosity about the world and its inhabitants that motivated the scholars who devoted themselves to the description of the earth and its inhabitants. The first steps had been taken in the east, when "Books of Routes," as they were called, were compiled for the use of the postmasters of the early 'Abbasid Caliphs. Soon, reports on far away lands, their commercial products and major physical features were compiled for the information of the Caliph

and his ministers. Advances in astronomy and mathematics made the plotting of this information on maps feasible, and soon cartography had become an important discipline in its own right.

Al-Khwarizmi, who did so much to advance the science of mathematics, was also one of the earliest scientific descriptive geographers. Basing his work on information made available through the Arabic translation of Ptolemy, al-Khwarizmi wrote a book called *The Form of the Earth*, which included maps of the heavens and of the earth. In al-Andalus, this work was carried forward by Ibn Muhammad al-Razi – Rhazes – who died in 936, and who wrote a basic geography of al-Andalus for administrative purposes. Muhammad ibn Yusuf al-Warraq, a contemporary of al-Razi, wrote a similar work describing the topography of North Africa. The wide-ranging commercial relations of al-Andalus allowed the collection, from returning merchants, of a great deal of detailed information about regions as far north as the Baltic. Ibrahim ibn Ya'qub, for example, who travelled widely in Europe and the Balkans in the late ninth century – he must have been a brave man indeed – left itineraries of his travels.

Two men who wrote in the 11th century collected much of the information assembled by their predecessors, and put it into convenient form. One of them, al-Bakri, is particularly interesting. Born in Saltes in 1014, al-Bakri was the son of the governor of the province of Huelva and Saltes. Al-Bakri himself was an important minister at the court in Seville, and undertook several diplomatic missions. An accomplished scholar, as well as *litérateur*, he wrote works on history, botany and geography as well as poetry and literary essays. One of his two important geographical works is devoted to the geography of the Arabian Peninsula with particular attention to the elucidation of its place names. It is arranged alphabetically, and lists the names of villages, towns, wadis, and monuments which he culled from the *hadith* and histories. His other major work has not survived in its entirety, but it was an encyclopedic treatment of the entire world.

Al-Bakri arranged his material by country – preceding each entry by a short historical introduction – and describes the people, customs, climate, geographical features and the major cities – with anecdotes about them. He says of the inhabitants of Galicia, for example: "they are treacherous, dirty, and bathe once or twice a year, even then with cold water; they never wash their clothes until they are worn out because they claim that the dirt accumulated as the result of their sweat softens their body."



Perhaps the most famous geographer of the time was al-Idrisi, "the Strabo of the Arabs." Born in 1100 and educated in Cordoba, al-Idrisi travelled widely, visiting Spain, North Africa, and Anatolia, until he eventually settled in Sicily, where he was employed by the Norman King, Roger II, to write a systematic geography of the world, which is still extant, and is usually known as *The Book of Roger*.

In it, al-Idrisi describes the world systematically, following the Greek division of it into seven "climes", each divided into 10 sections. Each of the climes is mapped – and the maps are highly accurate for the time in which they were compiled. He gives the distances between major cities, describes the customs, people, products, and climate of the entire known world. He even records the voyage of a Moroccan navigator who was blown off course in the Atlantic, sailed for 30 days, and returned to tell of a fertile land inhabited by naked savages. America?

The information contained in *The Book of Roger* was engraved on a silver planisphere, which was one of the wonders of the age.

Al-Andalus also produced the authors of two of the most interesting travel books ever written. Both exist in good English translation. The first is by Ibn Jubair, secretary to the Governor of Granada who, in 1183, made the Hajj, and wrote a book about his journey, called simply *Travels*. The book is in the form of a diary, and gives a detailed account of the eastern Mediterranean world at the height of the Crusades. It is written in clear elegant style, and is filled with the perceptive intelligent comments of a tolerant – and often witty – man.

The most famous of all the Andalusian travellers was Ibn Battuta – the greatest tourist of his age – and perhaps of any. He went to North Africa, Syria, Makkah, Medina and Iraq. He went to Yemen, sailed down the Nile, the Red Sea, Asia Minor, and the Black Sea. He went to the Crimea and to Constantinople. He went to Afghanistan, India and China. He died in Granada at the age of 73.

It is impossible to do justice to all the scholars of al-Andalus who devoted themselves to the study of history and linguistic sciences. Both were the prime "social sciences" cultivated by the Arabs, and both were brought to a high level of art in

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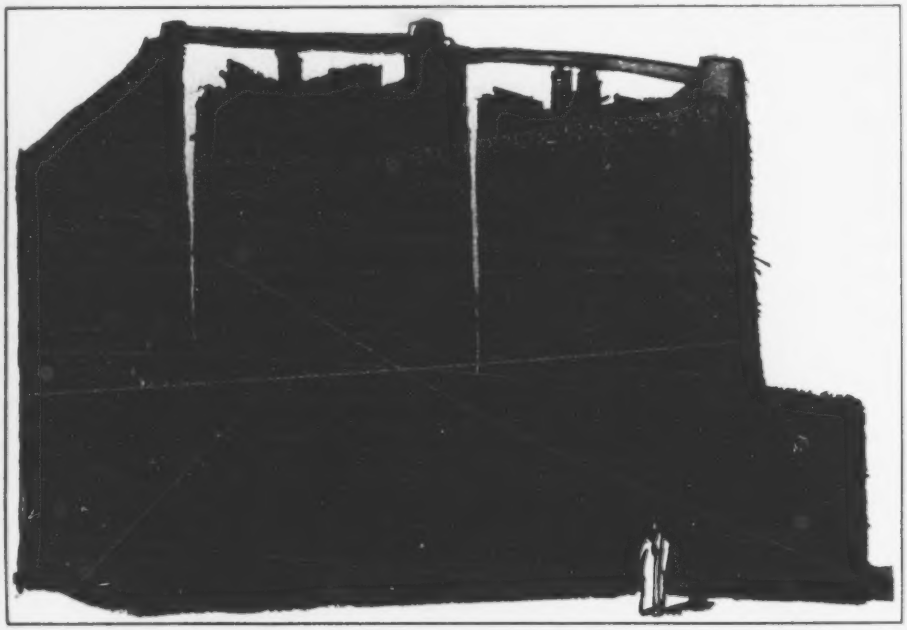

al-Andalus. For example, Ibn al-Khatib, whose theory of contagious diseases we have touched on already, was the author of the finest history of Granada that has come down to us.

Ibn al-Khatib was born in 1313, near Granada, and followed the traditional educational curriculum of his time – he studied grammar, poetry, natural sciences, and Islamic law, as well, of course, as the Koran. His father, an important official, was killed by the Christians in 1340. The ruler of Granada invited his son to occupy the post of secretary in the Department of Correspondence. He soon became the confidant of the ruler, and gained a position of great power.

Despite his busy political career, Ibn al-Khatib found time to write more than 50 books on travel, medicines, poetry, music, history, politics and theology.

The achievements of Ibn al-Khatib were rivalled only by those of his near contemporary, Ibn Khaldun, the first historian to seek to develop and explicate the general laws which govern the rise and decline of civilizations. His huge, seven volume history is entitled *The Book of Examples and Collections from Early and Later Information Concerning the Days of Arabs, Non-Arabs and Berbers*. The first volume, entitled *Introduction* gives a profound and detailed analysis of Islamic Society and indeed, of human society in general, for he constantly refers to other cultures for comparative purposes. He gives a sophisticated analysis of how human society evolved from nomadism to urban centers, and how and why these urban centers decay, and finally succumb to less developed invaders. Many of the profoundly disturbing questions raised by Ibn Khaldun have still not received the attention they should from all thinking men. Certainly, anyone interested in the problems of the rise and fall of civilizations, the decay of cities, the complex relationship between technologically advanced societies and traditional ones should read Ibn Khaldun's *Introduction to History*.

Another great area of Andalusian intellectual activity was philosophy but it is impossible to do more than glance at this difficult and specialized study. From the ninth century, Andalusian scholars, like those in Baghdad, had to deal with the theological problems posed by the introduction of Greek philosophy into a context of Islam. How could reason be reconciled with Revelation? This was the central question.

Ibn Hazm was one of the first to deal with this problem. He supported certain Aristotelian concepts with enthusiasm and rejected others. For example he wrote a large and detailed commentary on Aristotle's *Posterior Analects*, that abstruse work on logic. Interestingly, Ibn Hazm appears to have had no trouble relating logic to Islam – in fact, he gives illustrative examples of how it can be used in solving legal problems drawn from the *Shari'ah*. Nothing illustrates the ability of Islam to assimilate foreign ideas and acclimatize them better than Ibn Hazm's words in the introduction to his work: "Let it be known that he who reads this book of ours will find that the usefulness of this kind of work is not limited to one single discipline but includes the Koran, *hadith*, and legal decisions concerning what is permissible and what is not, and what is obligatory and what is lawful."

Ibn Hazm considered logic a useful tool, and philosophy to be in harmony, or at least not in conflict, with Revelation. He has been described as "one of the giants of the intellectual history of Islam," but it is difficult to form a considered judgment of a man who wrote more than 400 books, most of which have perished or still remain in manuscript.

Ibn Bajjah, whom western scholastic theologians called Avempace, was another great Andalusian philosopher. But it was Averroes – Ibn Rushd – who earned the greatest reputation. He was an ardent Aristotelian, and his works had a lasting effect, in their Latin translation, on the development of European philosophy.

Islamic technological innovations also played their part in the legacy of al-Andalus to medieval Europe. Paper has been mentioned, but there were others of great importance – the windmill, new techniques of working metal, making ceramics, building, weaving and agriculture. The people of al-Andalus had a passion for gardens, combining their love of beauty with their interest in medicinal plants. Two important treatises on agriculture – one of which was partially translated into Romance in the Middle Ages, were written in al-Andalus. Ibn al-'Awwam, the author of one of these treatises, lists 584 species of plants and gives precise instructions regarding their cultivation and use. He writes, for example, of how to graft trees, make hybrids, stop blights and insect pests and how to make floral essences and perfumes.

This area of technological achievement has not yet been examined in detail, but it had as profound an influence on medieval European material culture as the Muslim commentators on Aristotle had on medieval European intellectuals. For these were the arts of civilization, the arts that make life a pleasure rather than a burden, and without which philosophical speculation is an arid exercise. ■

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WRITTEN BY CHARIS WADDY
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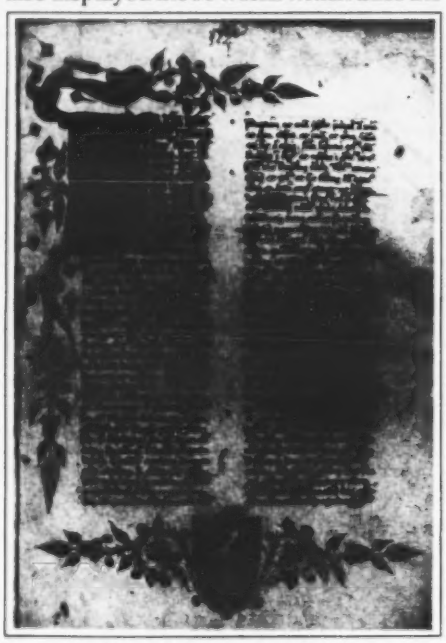
In 1981, to mark the opening of the 15th Islamic century, Oxford University's Bodleian Library scanned its collection of Arabic manuscripts – one of the world's largest – and mounted a display of 50 choice works to tell one of the great stories in the history of ideas: the flowering of philosophy and science in the medieval Muslim world and the transmission of that tradition – the *doctrina Arabum*, the teachings of the Arabs – to Europe.

With the influence of Islam again spreading and growing, and its intellectual traditions being revived, 1981 – which is 1401 on the Muslim calendar – was an especially appropriate year to open the Bodleian display. As Colin Wakefield, curator of the collection and organizer of the exhibit, said at the opening, "... the exhibition ... by focusing attention on the debt of medieval Europe to the scholars of the Muslim world, may shed an interesting sidelight on the long and turbulent history of relations between Islam and the West."

To display its Arabic treasures, Bodleian experts chose Oxford's Divinity School, built 500 years ago for the teaching of theology, then "queen of sciences." A splendid example of craftsmanship in the final flowering of the Gothic age, the Divinity School and the library above it – built by Duke Humfrey of Gloucester, brother to King Henry V – were a part of the outburst of building that occurred after the years of conflict with France and the civil strife known as the Wars of the Roses; this period produced the perpendicular Gothic unique to England and such structures as the new "College of All Souls of the Faithful Departed," a war memorial to those killed in the Hundred Years War, and, not far away, the Bell Tower of Magdalen College.

Today, beneath the richly carved, vaulted stone roof of the Divinity School, the surrounding library stores some of its greatest documents and manuscripts: the first folio edition of Shakespeare, one of the original copies of the Magna Carta and handwritten poems and letters by Shelley, Browning and Byron. In 1981, the library also displayed the 50 works which trace the



transmission of science and philosophy from the classical world to Europe along a route which ran eastwards through Byzantium to Baghdad, then, via Sicily and Spain, northwards to the centers of Europe at the very moment when hungry minds were eager for the food that centuries of Muslim civilization had to offer.

The manuscripts evoked two major periods of intense intellectual activity: Baghdad in the days of the early Abbasid caliphs – the ninth and 10th centuries of the Christian era – and the quickening of thought in 12th- and 13th-century Europe. Both these periods saw the indefatigable work of translators: first those who brought the corpus of classical knowledge to the Arabs and, 300 years later, those who passed it on to Western Europe enriched by the labors of Muslim scholars. It is this story that was the focus of the exhibit.

Take Aristotle, for instance. Only a fraction of his work was known in Europe during the post-classical era, when barbarian invasions caused the loss of so much earlier culture. But most of his books were translated into Arabic, and were studied and commented on over and over again in Baghdad and other centers. European philosophers rediscovered them via these commentaries. Ibn Sina (Avicenna) and Ibn Rushd (Averroes) were famous names in medieval philosophy, and their predecessor al-Farabi (Alfarabius) is said to have lectured on Aristotle's *Physics* 40 times and his *Rhetoric* 80 times.

At the Bodleian exhibit, the scope of the scientific tradition which reached Europe was shown in the headings of the exhibition: medicine. biology, alchemy and magic; astronomy and astrology; mathematics and optics. It was especially rich in the fields of medicine, mathematics and the early experiments in alchemy – which were to lead to the development of modern chemistry – for while 13th-century Paris excelled in philosophy, Oxford was ahead in science. Roger Bacon, for example, who is credited

with initiating the first developments in experimental science, was represented in the exhibition by his *Opus Tertius;* the third part of an encyclopedic work, it cites all the above named philosophers, as well as the astronomer al-Zarqali, and Ibn al-Haitham, whose works on optics had a great influence on early European scientists – and whose own works were also in the exhibition.

It is notable that many of the Latin manuscripts shown date from the 13th and 14th centuries – examples of the textbooks used in teaching and research in the universities of that period. They were housed in college libraries such as that of Merton College – which produced a sequence of brilliant mathematicians in pre-Renaissance times – or in the first library belonging to the university, a small building adjoining the University Church.

The main center of Latin translations from Arabic was Toledo, reconquered from the Arabs in 1085 and for 200 years a center in which Latin, Greek and Arabic were all in use. Another center was Sicily, where the Norman kings gathered a brilliant, multi-lingual court, which, at the Bodleian, was represented by a translation of a manuscript made for the Emperor Frederick II, who not only encouraged learning of all sorts but also kept a zoo, wrote on falconry, and was passionately interested in animals. The manuscript contains the zoological chapters of an Arabic encyclopedia, a famous work by Ibn Sina, *al-Shifa* — other portions of which were also displayed – dealing with physics and with the existence of the soul.

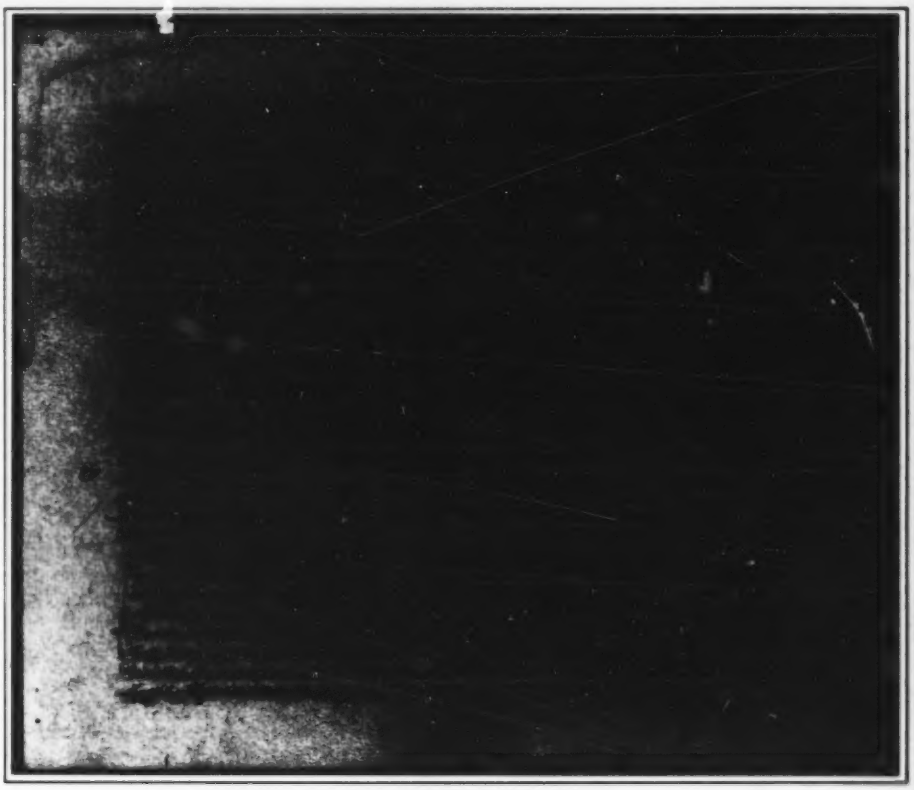
The zoological section of this encyclopedia was translated by Michael Scott, a contemporary of Roger Bacon. Scott, whose studies in astrology gave him a sinister reputation as a magician, was probably from Scotland, and traveled south in search of the new learning. As was the custom then, the equivalent of today's doctoral candidate would make his way, on foot, to Spain, and perhaps Sicily as well, to hear "the wisest philosophers in the world," and return bringing some fresh work which scientists at home – Bacon and others – would incorporate in their teaching and research. Scott worked as a translator in Toledo for some years, then went to Sicily, where he was appointed Court Astrologer to Frederick II. No doubt he took with him the translation he had already made of Aristotle's writings on animals, for an interest in the animal world would find favor with the emperor.

Botany and agriculture follow zoology, and anthropologists undoubtedly took special note of Ibn Wahshiyya's *al-Filaha al-Nabatiyya*, a treatise on farming which gives a wealth of facts about popular customs, religion and magic as well as agricultural and botanical information. Another vital work, basic to the study of pharmacology, is the *De Materia Medica* by Dioscorides, a Greek writer of the first century. It led to the science in which the Muslims excelled: medicine.

In the history of medicine, a number of books from Arab sources became standard texts reproduced first in manuscript and later in print. Works by the fathers of Greek medicine, Hippocrates and Galen, for example, were known to the Arabs and translated into Arabic during the eighth and ninth centuries. Under the caliph al-Ma'mun, son of Harun al-Rashid, a translation center in Baghdad, known as *Bait al-Hikma*, the House of Wisdom, was established, at which the outstanding Hunain ibn Ishaq is said to have translated 100 books by Galen, Hippocrates and other physicians. Later, Hunain's own authoritative *Introduction to Medicine* was translated into Latin – and remained a popular manual of instruction for 600 years. His only rival was Gerard of Cremona, the greatest translator of the Toledo school. When he died, his pupils drew up a list of 71 of his translations – and it was not exhaustive. One of his greatest contributions, a version of Avicenna's *Canon of Medicine* (Ibn Sina's *al-Qanun fi al-Tibb)*, was used in both Europe and the Islamic world from the 11th to the 17th centuries and, during the 15th and 16th centuries, was printed at least 35 times in Europe.

Another of Gerard's translations was of a book on surgery, by al-Zahrawi, who practiced medicine in al-Andalus in the 11th century. The various Latin printed editions of his work include one published in Oxford in 1778. Diagrams of surgical instruments found in the Arabic manuscript are copied in the translation.

Alongside these major texts was shown a smaller one, a traveler's manual with medical advice by a North African doctor who died about 1004. This manual was popular in the Muslim world, and it



became equally so in Europe when one of the first medical translators, Constantinus Africanus, produced a Latin version – which he claimed as his own work.

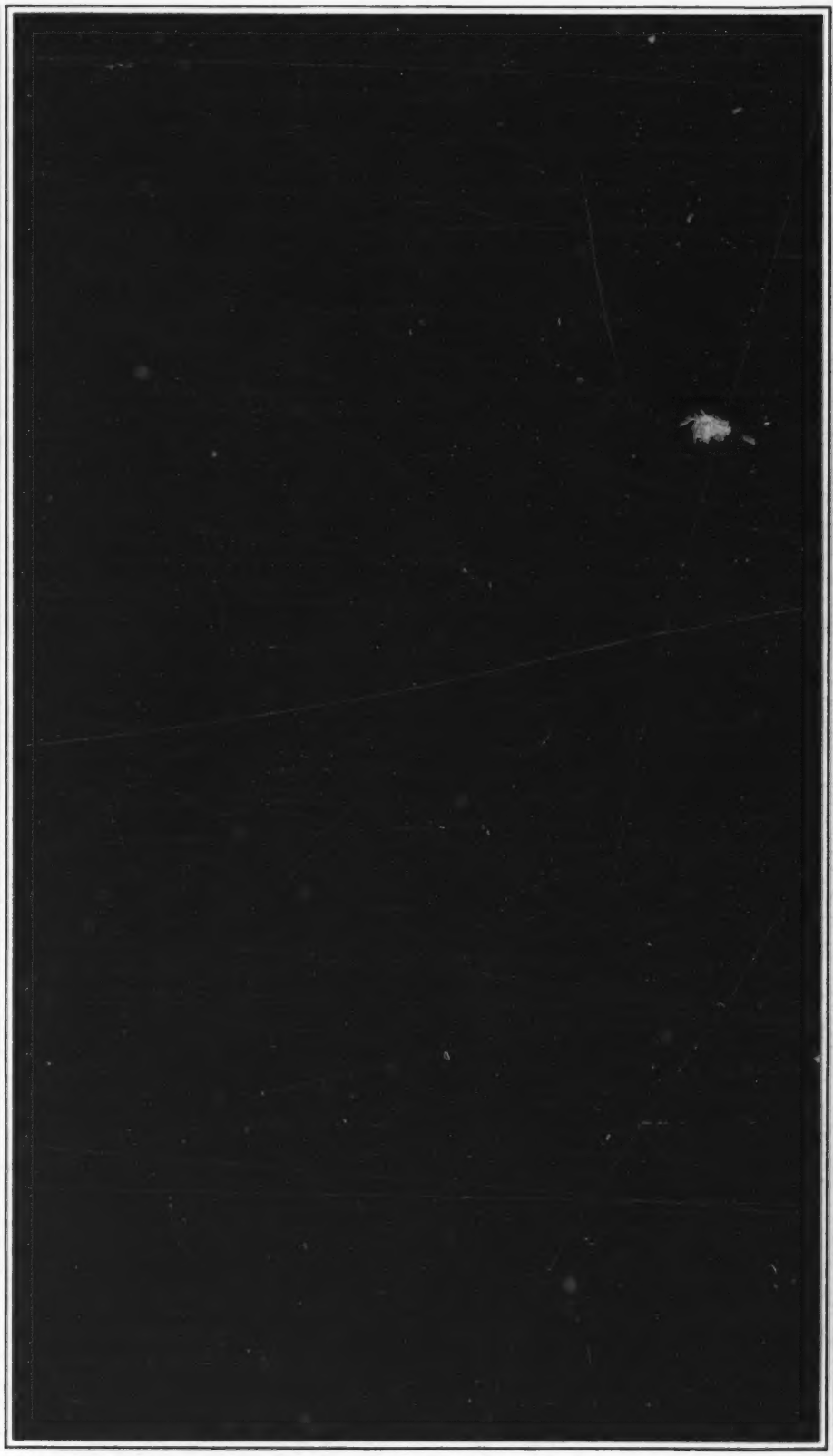
One other name that must not be omitted is that of Maimonides, the Jewish scholar, philosopher and physician who left Cordoba for Egypt and practiced medicine in Cairo in the time of Salah al-Din (Saladin). One of his numerous medical works was a regimen of health prepared for the son of Saladin, who succeeded his father as ruler of Egypt. Also shown is Maimonides' *Guide to the Perplexed*, composed, as was customary for Jewish authors at the time, in Arabic, but written in the Hebrew alphabet.

Moving on to astronomy and mathematics, the exhibit showed the debt of European astronomers to their Eastern counterparts for the foundations on which all subsequent advances in scientific study were to be built. Included, for example, was the mathematician al-Khwarizmi, who worked in Baghdad and drew up some of the earliest astronomical tables used by the Arabs. Revised in Cordoba, these tables were translated by Adelard of Bath, whose Latin version was used by many early European astronomers.

In another book, also shown in the exhibition, the same al-Khwarizmi introduces algebra to Europe. But his most important contribution was the introduction – via Baghdad – of the Indian system of numerals, which, in the 13th century, began to replace the cumbersome Latin system of numeration. Renamed "Arabic numerals," they spread from the merchants of the Mediterranean ports into every sphere of life.

Geometry was also represented at the Bodleian exhibition – in one of the great classical works: the *Conics* of Apollonius of Perga. It consisted of seven books, three of which survive *only* in Arabic translation. The Oxford astronomer Edmund Halley – famous for his observation of the comet known by his name – used Bodley's Arabic manuscript of the *Conics* in preparing a complete edition of that work, published in 1710.

Other Oxford astronomers in the 17th century also drew on Muslim sources – such as the star tables worked out in the magnificent observatory in Samarkand, built in the 15th century by Ulugh Beg, a grandson of Tamerlane. These astronomi-



cal and chronological tables were an advance on those of previous scientists. They became known in Europe in the 17th century, and the Savilian Professor of Astronomy, John Greaves, obtained and used the manuscript exhibited here, in preparing the tables for publication with a Latin translation: a continuation five centuries later of the 12th-century practice.

Finally, two manuscripts deal with the making of scientific instruments – another field in which much was owed to Islamic sources. One of the earliest astronomers to write in Arabic – also an astrologer at the court of the caliph al-Mansur, who firmly established the Abbasid dynasty – was Masha' allah (Messahalla), whose writings are only known in Hebrew and Latin translations. Masha' allah draws on Indian and Persian sources as well as Arabic and classical, and the Latin translation of his *De Compositione Astrolabii* showed how to construct that basic tool of observation and reckoning of time: the astrolabe. Later Chaucer drew on Masha'allah for his *Treatise on the Astrolabe*, a charming piece of prose, explaining to a 10-year-old boy the use of this scientific instrument. Chaucer's writings, full of references to Arab sources, whether in the form of tales or of learning, show how far such elements had penetrated the general thinking of his day – 100 years after the

translators had completed most of their work.

In such a limited selection of the Bodleian's wealth, of course, there had to be significant omissions. One was a delightful picture of Roger Bacon at work in his study, another the book of maps composed by the Sicilian Arab, al-Idrisi, greatest of all medieval geographers, and a third the first translation of the Koran into Latin, begun in 1142 in Toledo by an English scholar.

With all its imperfections, this translation represented the first Christian attempt to take an objective view of the Koranic text. Four centuries later, at the height of the hysteria aroused by the Ottoman invasions of Hungary and Austria, this same translation was courageously printed in Basel by the Swiss theologian Bibliander – and the Bodleian has a fine 13th century manuscript of the original translation, as well as copies of the two first printings in Basel.

To Muslim scholars whose work was shown in the exhibition, the Koran was the summation of human knowledge. The source of all knowledge was God's revelation – as indeed it was for their Christian counterparts. Faith inspired all these men, whether expressed in the Oxford motto *Deus illuminatio mea*, the Psalmist's *The heavens declare the glory of God*, or the Koranic *God is the light of the heavens and the earth*. The Muslim custom of beginning every piece of writing with praise and thanks to God reappears in the Latin translations of Islamic works of scholarship. For example, *The Canon of Medicine* of Ibn Sina, translated by Gerard of Cremona in Toledo from Arabic to Latin, begins with, "Let us first give thanks to God . . . whose mercies are manifest upon all the Prophets." Muslim philosophers also threw light on the relationship between faith and reason – as live a question today as it was when Bacon studied Avicenna's commentaries on Aristotle.

What is the point of recalling this story of the transmission of ancient knowledge today – when scientific texts are said to be out of date almost before they are printed? Is the history of the development of the astrolabe likely to be relevant in the age of the computer?

The answer to these questions lies in the fundamental precepts of scholarship – and of human nature. It is human beings who acquire and use knowledge. One constant factor in research is the variable, volatile mixture of emotions and purpose which motivates those who pursue it. Their passion for truth and their boldness in exploration demand a rigorous discipline and an integrity of aim not to be deflected by the jealousies, the insecurities, the ambitions common to man. Intellectual integrity also demands a generosity of spirit, giving credit where credit is due, enhancing the other man's contribution rather than diminishing it.

One lesson can be drawn from the story of 12th- and 13th-century Europe and its advances in scholarship. Relationships between intellectuals can play an important part in times of conflict, in preparing the way for a better future. For it must not be forgotten that the period of the translators was also the period of the Crusades.

The real points of contact, of course, were not on the battlefields of Palestine, but were in the court of Palermo and the libraries of Toledo, where Christian, Muslim and Jewish scholars – using Latin, Greek, Arabic and Hebrew – achieved a cooperation important to the whole future of Europe.

These vital points of contact have largely been forgotten. Bacon, for example, spoke against military endeavor, and took account of Islam's positive contribution to the divine scheme of revelation. He and others had some grasp of the common basis of faith of Muslims and Christians.

Thus a tribute – in gratitude for a long forgotten debt owed by European scholarship to the Muslim world – was neither out of place nor out of date; it was a timely reminder which may smooth the path toward future cooperation, and which illuminates the possibilities of give-and-take between scholars, in a turbulent age. ■

SCIENCE IN THE MODERN AGE

WRITTEN BY RICHARD HOBSON – WITH JOHN LAWTON, ROBERT FRAGA, ARTHUR CLARK AND MARTIN LOVE
PHOTOGRAPHS BY S. M. AMIN AND BURNETT H. MOODY – WITH TOR EIGELAND, NIK WHEELER, ROBERT AZZI, JOHN CHAMPNEY, KATRINA THOMAS, TERRY WEBB AND ABDULLAH DOBAIS

More than 1,000 years ago, as Europe languished in the Dark Ages, Islamic astronomers were building observatories and Islamic scientists were working out the principles of algebra, laying the foundations of optics and even attempting to fly.

This was the era of *Bait al-Hikma*, the "House of Wisdom," an early version of today's "think tanks," from which came translations of Greek mathematical and scientific papers, breakthroughs in geometry and, eventually, discoveries in everything from hydrology to medicine – which were transmitted to the West.

As the tides of history ebbed and flowed, however, the West gradually caught up and surpassed the Islamic world in science and technology, and by the time of the Industrial Revolution, the Islamic countries had been eclipsed.

Though the Muslim world was painfully aware of the gap, there was very little they could do to bridge it. Lacking the infrastructure to develop industry, all they could do was import know-how and equipment. And though this system of modernization – as distinct from the slow, trial-and-error approach – was expedient, it also tended to foster an unhealthy dependency.

On the other hand, this influx of outside scientific and technological influence – coupled with large scale development programs – also kindled a new interest in the study of the sciences. In the 1970's and 1980's consequently, the number of Arabs pursuing scientific careers mushroomed. Over the past 30 years, in fact, the number of Arab students earning degrees from colleges or universities in the Arab world increased at a geometric rate: nearly doubling every five years since the early 1950's. By 1975, there were about 760,000 graduates, and by 1980 close to 1.5 million.

This enormous growth was documented by Lebanese scientist Dr. A. B. Zahlan in his book, *Science and Science Policy in the Arab World* (1980, Croom Helm Ltd, London). A concerned critic of Arab science, and a leading authority on the application of science and technology to development, Zahlan said that:

> The Arab World is at the threshold of momentous changes that are being heralded by the increasing access to higher education. Within the following two decades, if the trends of the past three decades persist, more than 12 million Arabs will graduate from universities in the Arab world. Of these, at least six million would have received an education in the applied or basic sciences.

It would be misleading, nevertheless, to imply that more science graduates will lead automatically to increased scientific research. Of those who have the inclination, aptitude, facilities and financial backing to pursue genuine research, many have to settle for applied rather than pure science; in today's economic climate, pure research is an indulgence few can afford.

Saudi Arabia's approach to this issue is similar to that of other Arab governments. While the kingdom is determined to establish a solid domestic base for scientific research, it has emphasized that Saudi researchers should concentrate on concrete rather than theoretical issues. In fact, a key objective of the kingdom's Fourth Development Plan (1985-1990) is to "harness" scientific and technological research and development to long-term national goals: diversifying the economy, reducing manpower requirements, improving productivity, and promoting a higher standard of living.

This philosophy also guides the policies and activities of several national scientific organizations that have been set up in the Arab world in recent years. A prime example is Saudi Arabia's King Abdulaziz City for Science and Technology (KACST).

Founded in 1977 as the Saudi Arabian National Center for Science and Technology (SANCST), this central body for coordinating scientific research in the kingdom changed its name in 1986 – well ahead of its move to a spanking new $307 million headquarters in Riyadh.

Opened in phases, the science city eventually may house national research institutes for instrumentation, energy, industry, natural resources and the environment, petroleum and petrochemicals, arid lands and astronomy.

Among the first projects at the science city scheduled to come on stream is a remote sensing station to receive digital data

from the orbiting multispectral scanners on the American LANDSAT and French SPOT satellites. The station will have the capability to both decode the data into images of the Arabian Peninsula's surface and enhance these images to provide specific information about geology, water resources, vegetation, population densities, land usage and many other fields. The receiving station was scheduled to begin operation in late 1986, with the image processing center to follow in 1987. At $40 million, the facility will be among the world's most advanced.

The new science city will build further on the groundwork laid by SANCST to both encourage internal Saudi research and draw upon outside expertise. Indeed, the national science center has already achieved a remarkable degree of international cooperation in its effort to bridge the scientific and technological gap.

For example, the U.S. National Science Foundation helped train Saudi personnel at SANCST and helped develop its programs; the Royal Meteorological Institute of Belgium processed data collected by SANCST to produce a national atlas of solar radiation, a key reference manual for the many solar experimenters in the kingdom. And under a technical cooperation agreement signed with West Germany, joint research was done in hydrology, waste water treatment, industrial development and solar energy applications, including the design and planned construction in Saudi Arabia of a solar plant to produce hydrogen. Importantly, the agreement allowed each nation to plug into the other's computerized scientific data banks.

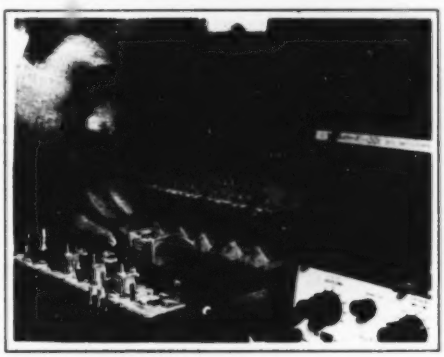
As another example, the Canadian National Research Council helped lay plans for a national observatory in the kingdom, and in early 1986 KACST was evaluating voluminous data on three possible sites.

South Korea's Advanced Institute of Science and Technology was also involved in two important KACST projects: development of native construction materials and improvement of local animal feeds. Analysis of such local materials as gypsum is being watched closely by the Saudi Ministry of Housing and Public Works and by the Saudi Arabian Standards Organization, because the kingdom could save billions of dollars in imported construction materials by better development of its own natural resources.

In the other project, funded at $2.6 million, researchers were hoping to find substitute feed for expensive imported varieties used to sustain the kingdom's growing livestock industry. According to KACST officials, this project too could eventually yield important dividends.

The center's most ambitious and far-sighted international project, however, is SOLERAS (Solar Energy Research American Saudi). By 1986, this $100 million joint venture with the U.S. Department of Energy had established large-scale solar energy experiments in both countries.

Among SOLERAS's major achievements is the world's largest concentrator photovoltaic power system (See *Aramco World*, September-October 1981). Designed and manufactured by Martin Marietta Corp.'s Aerospace Division, it was installed 50 kilometers northwest of Riyadh (30 miles), and by 1986 had already produced 375 kilowatts of power at its peak and was providing electricity to 4,000 villagers. During 1986, the site was being further developed as a research station to test new photovoltaic design concepts, including some that rely on wind-powered generators for auxiliary power.



In February 1985, SOLERAS also switched on a solar-powered desalination plant in Yanbu' on the Red Sea. A prototype, the $29.7 million project is important not only for Saudi Arabia, whose huge conventional desalination plants consume large amounts of fossil fuel, but also for other desert regions that do not have cheap supplies of oil or natural gas. Though the plant encountered serious problems from accumulating dirt and rust – which contaminated the ammonia on the system's freezer heat exchanger – measures were taken to correct the problem, and soon the plant achieved a peak production rate of 47,551 U.S. gallons of treated water a day (180 cubic meters) – 90 percent of its design capacity.

In other important projects, SOLERAS has sponsored advanced basic and applied research at nine American universities and funded four projects in the U.S. to test advanced active solar cooling systems in commercial buildings – leading Dr. Bakr Khoshaim, director of KACST's solar energy programs, to call SOLERAS "a model of cooperation between two nations in pursuit of a technology which will benefit them both." Within the kingdom, it established solar laboratories at four universities: King Sa'ud University (KSU) in Riyadh, the University of Petroleum and Minerals (UPM) in Dhahran, King Faisal University (KFU) in Dammam and King Abdulaziz University (KAU) in Jiddah.

Outside of the SOLERAS agreement, KACST's Solar Energy Department was pursuing other projects on its own. In one, field tests were being conducted for the Ministry of Communications on photovoltaic highway devices, including lighting in tunnels and on traffic signs.

Through its program of offering 30-40 applied research grants a year to scientists at Saudi universities, KACST was also spreading scientific activity throughout the kingdom. With its 1986 proposals, KACST has awarded about 250 grants to individuals or teams of researchers since it started the program. In 1984-85 alone, KACST received about 350 proposals, suggesting the degree to which scientific activity has taken root at many of the kingdom's seven universities.

Several of the kingdom's scientific projects have been concerned with health and medicine. In one, experts from the London School of Hygiene and Tropical Medicine teamed up with personnel from KFU to study leishmaniasis, a parasitic disease transmitted to humans by sand flies. By 1986, the four-year study had tested treatments at a special clinic in al-Hasa and established baseline epidemiological data. The Ministry of Health hopes this information will help eradicate the disease both in al-Hasa and elsewhere in the kingdom.

Another national project, again involving the Ministry of Health, was drawing on researchers at KSU in an investigation of folk remedies in the kingdom; the study was evaluating their actual versus purported curative effects, and analyzing the chemistry of specific folk drugs.

In history, of course, there is strong Islamic precedent for commitments to medical science. Muslim scientists, for instance, discovered the circulation of the blood in veins centuries before Harvey did, worked out principles of infectious disease and performed delicate eye operations with a skill not duplicated until modern times. During the medieval period, Islamic physicians also founded hospitals throughout Middle Eastern urban centers – including Makkah (Mecca) and Medina on the Arabian Peninsula.

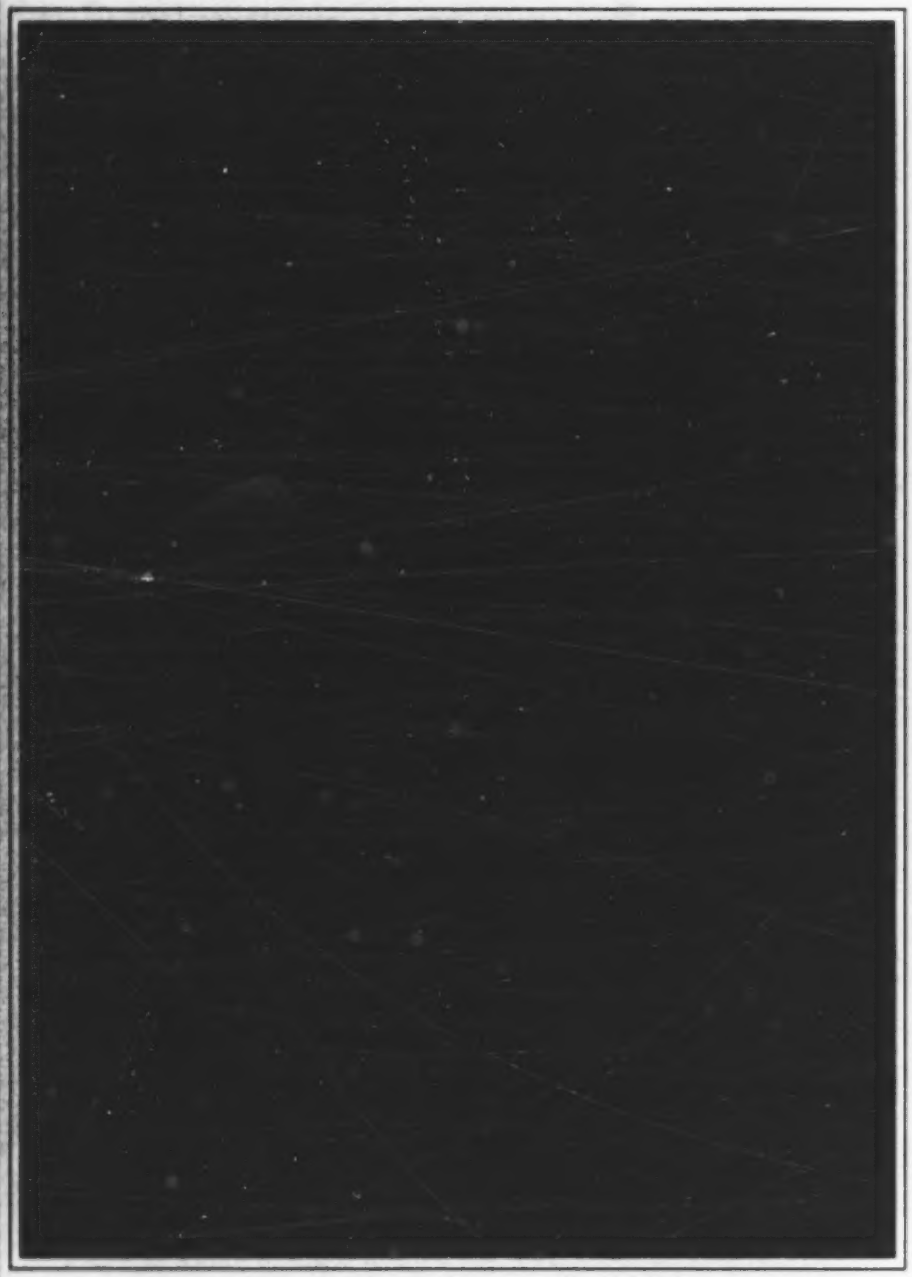
It is particularly appropriate, therefore, that Saudi Arabia today boasts *four* medical schools – in Dammam, Riyadh, Jiddah and Abha – and some of the most advanced medical facilities found anywhere. These include King Faisal Specialist Hospital (KFSH), its related Cancer Research Institute and King Khalid Eye Specialist Hospital – all in Riyadh (See *Aramco World*, July-August 1979 and September-October 1984). All three are important institutions in the region and serve as essential domestic training grounds for Arab medical specialists.

There is perhaps no better single example of medical progress in the kingdom than an event which occurred February 14, 1986, and suddenly thrust Saudi Arabia into the international limelight and the medical big leagues. On that day, at Riyadh Armed Forces Hospital, a team of surgeons led by Dr. Rashid al-Faqih transplanted a healthy heart from an accident victim into the chest of an ailing two-year-old child. It was the first such operation in the Middle East.

Clearly, Saudi Arabia is ahead in its rapid acquisition of scientific and technological resources – and in its commitment in these fields. But it is by no means the only Arab country backing scientific activity. Egypt, for example, has been a Middle East pathfinder ever since the 1950's, when its technical manpower more than quadrupled and four major new scientific institutions were founded: the Supreme Science Council, the Atomic Energy Agency, the Desert Institute and the National Research Center – once ranked as the largest scientific institute in the Arab world. In 1971, Egypt also set up the Academy of Scientific Research and Technology to organize applied research in such areas as food, agriculture and water resources – especially the impact of the Aswan High Dam.

Other countries were active, too. In Syria the Scientific Studies and Research

Science : The Islamic Legacy



Unit, established in 1972, focused on applied and industrial chemistry, applied physics, electronics, mechanical engineering, science policy and computer science; it also conducted studies of housing costs, banking activities, water distribution, telecommunications and land reclamation. And in Iraq, rapid development of its scientific and technological potential has been given high priority. The Foundation for Scientific Research, established in 1963, had, by 1986, established specialized bodies in such fields as agriculture, petroleum, natural resources, building, palms and dates, biology, and documentation. As early as 1972, Iraq's Nuclear Research Institute (NRI) had provided critical technical studies of corrosion in oil and gas pipelines and of radioactive materials in hydrology. By 1986 NRI had a range of research departments, working on nuclear reactors, physics, chemistry, engineering and instrumentation, biology and geology.

In Lebanon, scientific research was sparked by the creation of the National Council of Scientific Research – which began awarding research grants in 1968 – and in Jordan, the Royal Scientific Society, founded in 1970 as an independent, nonprofit research and development organization, was working in the fields of education, economic research, electronic and mechanical engineering, and computer systems.

Not surprisingly, given the traditional Islamic-world problems with farming, much scientific research has focused on agriculture – and still does today as scientists from Aleppo to Abu Dhabi grapple with the urgent problem of feeding growing populations from depleted land.

Centuries ago, what is now the Arab East was the granary of the known world, as well as the birthplace of the date palm and the site of ingenious advances in irrigation. Gradually, however, war, pestilence and drought destroyed the region's fertility until, up to a decade ago, extensive agriculture was deemed impossible in the region – 90 percent of which was desert.

Today, though, agricultural history is once more being made in the Arab world. In Saudi Arabia, agricultural scientists are growing tomatoes and cucumbers without soil. In Libya and Oman, agronomists have created great circles of watered farmland in the deserts; in the United Arab Emirates, an asphalt carpet has been laid beneath the sand to prevent water loss, and in Syria scientists have developed new "miracle" strains of traditional Middle East crops.

None of these experiments is entirely new to the Arab East: in the 1960's the Arab Lands Agricultural Development Program (ALAD) was already working hard to improve the productivity of the region. But ALAD's research program has been carried even further by the International Center for Agricultural Research in Dry Areas (ICARDA), an extension of the global network of agricultural scientists who helped bring the "green revolution" to Asia, Africa and the Americas with "miracle" wheat and rice. ICARDA, in 1977, began similar experiments with the basic crops of the Middle East: wheat, barley, lentils, broad beans and chickpeas (See *Aramco World*, May-June 1978) and subsequently made a series of break-

throughs in agricultural research that are already helping improve the staple diet of the peoples of North Africa and the Middle East. These, said Dr. Muhammad Nour, the director, included the development of five new types of high-yielding, better-tasting cereal that in 1986 were being incorporated in the growing programs of numerous nations of the region; successful introduction of a new, more nutritious variety of Faba bean in the Nile Valley; and development of a new type of disease-resistant chickpea, another basic food of the Arab East.

Under such programs as the whimsical-sounding acronym FLIP (for Food and Legume Improvement Program), ICARDA also developed new harvesting techniques for lentils, which reduce labor costs and make cultivation of stony soils economically feasible. In addition, ICARDA trained over 867 agricultural scientists and technicians from North Africa and the Middle East.

This research, of course, is aimed at increasing output from acreage already under cultivation, but other experiments were designed to expand cultivable land. By tapping so-called "fossil" water – which has been locked beneath the desert for thousands of years in aquifers – drawing it to the surface and sprinkling it over the sand from huge booms revolving horizontally on wheels, scientists created great discs of farmland in previously arid areas in Libya and Oman. And in the United Arab Emirates (UAE), agricultural scientists laid a three-millimeter-thick carpet of asphalt under the sand at a depth of one meter. The "carpet" prevents irrigation water from soaking into the sand and also stops salt seeping up from the subsoil on a five-acre experimental farm in the Salaymat district of Abu Dhabi.

As a result of such innovative experiments, UAE crop values rose 76 percent between 1977 and 1980, and Saudi Arabia had become self-sufficient in wheat - with a record 1.7-million-ton crop in 1985.

But Saudi Arabia, concerned at the depletion of aquifer water, had also launched a search for alternatives. By 1986 the kingdom was recycling sewage effluent to irrigate urban landscaping, was using agricultural drainage water to irrigate crops; had created artificial lakes and dams to recharge ground water reservoirs, and was developing detailed water management schemes for its agricultural development companies.

Meanwhile, successful experiments in fish farming and hydroponics – growing vegetables without soil – had already spawned private commercial ventures in these areas, and researchers were testing the possibility of using certain plant species, tolerant of highly saline soil conditions, as animal fodder. Other researchers were applying solar energy technology to agriculture: environmentally controlled greenhouses using active or passive solar cooling and heating systems.

To consolidate these gains in agriculture, as well as in energy, medicine, pollution control, hydrology and many other fields – and to coordinate research efforts – several *regional* organizations were set up too – another indication of how much science in Arab countries is focused on development. Some examples are the Arab Regional Center for the Transfer and Development of Technology, the Arab Fund for Scientific and Technological Development and the Union of Arab National Research Councils. Another important group is the Conference of Ministers of Arab States Responsible for the Application of Science and Technology to Development (CASTARAB).

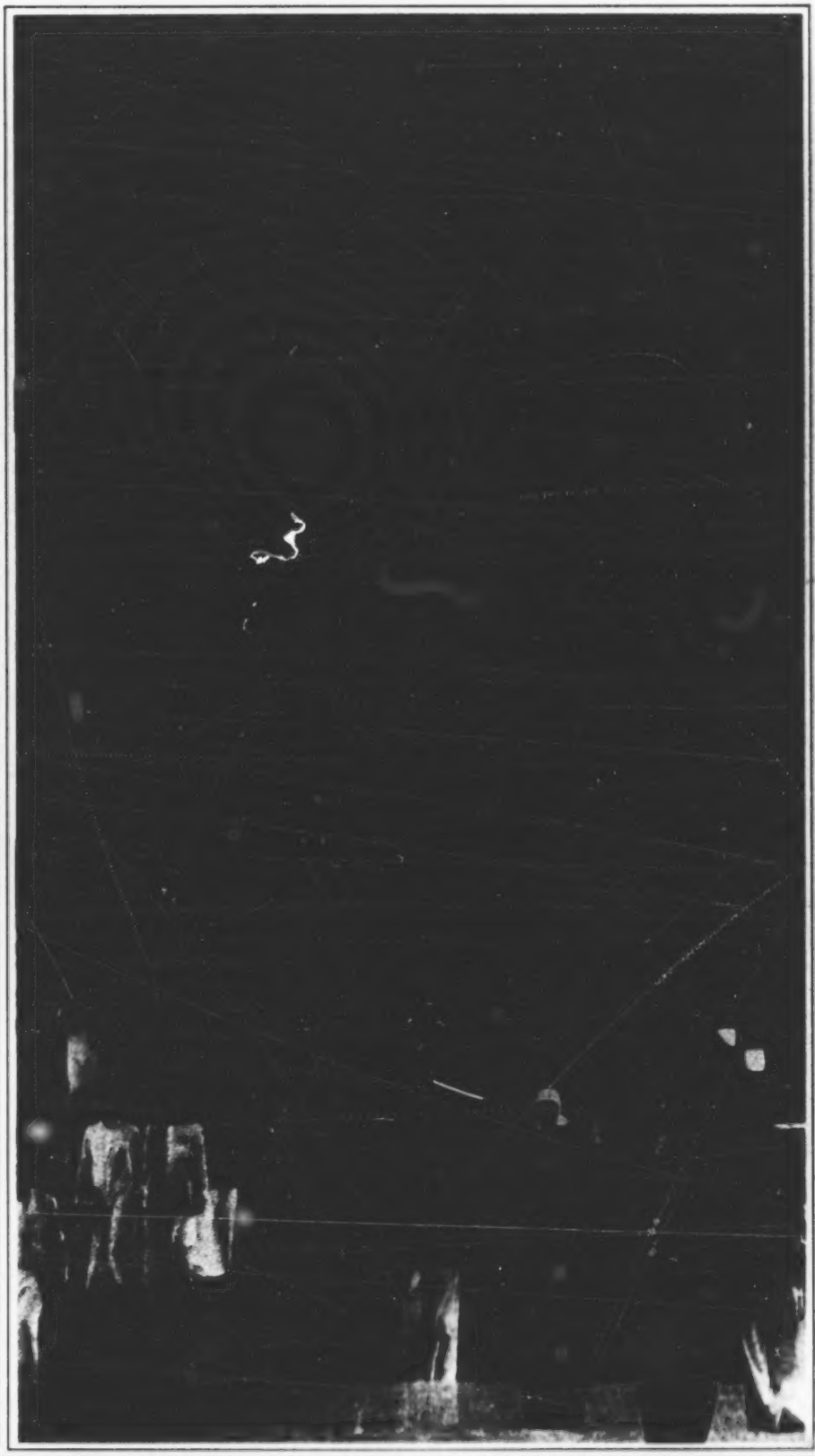
Some countries can do more than others, of course; not all the countries in the Islamic world have been blessed with petroleum riches. As a result, scientists – and potential scientists – frequently emigrate in frustration.

Dr. Zahlan once estimated that fully half of those Arabs who hold doctoral degrees emigrated because of insufficient support in their native lands. "National support for research and development activity," he warned, "is very low."

Other authorities on science policy in the Islamic world have long held similar views. In 1986, in fact, one went so far as to say, "No Muslim country in the Middle East or Africa possesses high-level scientific and technological competence attaining to any international level in quality."

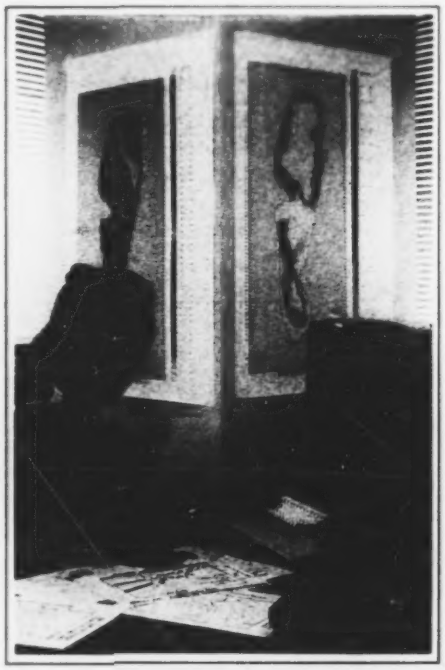
He also said that to prevent Muslim scientists from "making exiles of themselves," Middle East oil-producing countries should establish a $1 billion foundation to support some 4,000 Muslim scholars a year in both applied and pure scientific research. He added too that the Islamic world needs 50 independent foundations of science, technology and science education if a modern scientific renaissance is to take root – and that such a revival hinges on five cardinal principles: passionate commitment, generous patronage, provisions of security, self-government and internationalization.

Unfortunately, with revenues from oil exports having dropped precipitously since 1984, even the relatively well-off oil-producing states of the Middle East will be hard-pressed to allocate the amount of funding that some observers believe necessary. Saudi Arabia, one of the most committed Islamic states, had earmarked about half a billion dollars for programs in



science and technology during its 1985-1990 Five Year Plan, but much of that will be spent on construction of projects like the new KACST campus in Riyadh rather than research. Of the total, $128 million will support actual research and development. The government stipulated, moreover, that the award of research grants would hinge increasingly on the economic feasibility of the proposals and on their applicability to specific problems and needs.

Nevertheless, there is little doubt that modern scientific activity has taken firm hold in many Muslim countries and that considerable investments to build on that base will continue. Two outstanding science centers in the Islamic East clearly illustrate the strides that have been made: The Research Institute at the University of Petroleum and Minerals (UPM) in Dhahran, and the Kuwait Institute for Scientific Research (KISR).



At these institutes Muslim scientists are collecting and absorbing scientific and technological knowledge from the world's most highly industralized nations and – far more significant – are attempting to transform it, adapt it, and redigest it in a form palatable and usable in their own societies and others in the Arabian Gulf and beyond.

To compare the efforts of these institutes to *Bait al-Hikma* of Baghdad – as some observers tend to do – may seem an exaggeration, but it is not just romantic yearning for the Golden Age; real parallels *do* exist. Ninth-century Islamic scholars, after all, also collected and absorbed a wholly alien intellectual tradition and, from an intellectual fertilization cutting across national, linguistic, religious and cultural boundaries, built a renaissance upon it.

In Kuwait and Saudi Arabia, furthermore, inquisitive and highly educated native minds are joining others from the Islamic world and the major science centers of the West and Far East. As scholars at the House of Wisdom looked to Byzantium and beyond, those at UPM and KISR are reaching out to Tokyo, to Pasadena – and to points in between.

It is important to remember that both institutes are relatively young by world standards; KISR was founded in 1967 and UPM's institute a decade later. In a sense, they are the instant offshoots of newly prosperous societies. While each has enunciated a clear determination to *apply* Western technology and not just swallow it wholesale, neither holds any illusions that it can – in the words of one study on the issue of development – change from "technology taker" to "technology maker" overnight. In fact, the institutes are themselves bold experiments: at the UPM Research Institute, for instance, scientists are working out of a six-story edifice which, though simply called "Building 15" is what institute director Dr. Abdallah Dabbagh calls "the most modern scientific research facility in the Middle East."

Even a casual inspection suggests that this is no exaggeration. But the institute's heart is in its dozens of high-tech laboratories, which have spilled out of Building 15 into a nearby extension. Among the newest are laboratories to support the Petroleum Refining and Petrochemicals Section and laboratories for research in laser chemistry and physics, high time-resolution and laser diagnostics.

Perhaps the most exciting new addition to the Research Institute is its nuclear physics laboratory, which was expected to be fully operational by 1987. Housed in its own building on the UPM campus, the facility includes a 350-kilo-electron-volt proton, deuteron and helium positive-ion acceleration system and a low-voltage "Tandetron" system. The accelerators and their associated laboratories are designed to support wide-ranging nuclear research and are part of an initiative in the kingdom to develop nuclear energy for peaceful purposes, for which the Fourth Development Plan allocates $22 million through 1990.

According to Dr. Dabbagh, who holds a Ph.D. in structural geology from the University of North Carolina, "transfer of technology does not take place without original applied research." Accordingly, many of the investigations by the institute have been directly related to three environmental factors that dramatically affect life in the Arabian Peninsula: the sun, sand and sea.

As noted, the kingdom has long supported research in solar energy and the Research Institute was an early beneficiary of national grants in this field. Shortly after Building 15 opened, a comprehensive monitoring station to measure 16 solar and meteorological parameters was installed on its roof to help scientists measure the energy potential of Arabian sunlight. The project established important baseline data subsequently used to test the efficiency of solar systems erected in the field.

If Arabia's blistering sun is a blessing in disguise, its drifting sand is not. Sand, in fact, threatens billions of dollars of infrastructure. Therefore, the institute and some of its clients have made sand experiments an important priority.

Most of the institute's recent work in this field has been carried out under contract to the Royal Commission that administers Jubail Industrial City, a sprawling industrial and residential complex built from scratch on the eastern coastal plain. There, a 21-man team headed by Dr. Talat Bader used calibrated traps to collect more than 2,000 samples of blown sand which were analyzed for grain-size distribution and gross mineralogy. By measuring the gross weights for more than 1,500 samples, they also calculated the rate of sand movement in different locations. They studied the hydrology of the region to determine what types of vegetation could be introduced to limit sand migration. They tested four types of fencing – palm leaf, wooden snow fence, jet fence, and paraweb – on parabolic and, barkhan dunes as well as dredge-fill material. Finally, 13 commercial chemicals were applied in different experimental patterns on a variety of geomorphs to determine their relative benefits as sand stabilizers.

Results of the study, contained in 11 volumes, include specific recommendations for what may develop into the largest sand control project ever undertaken.

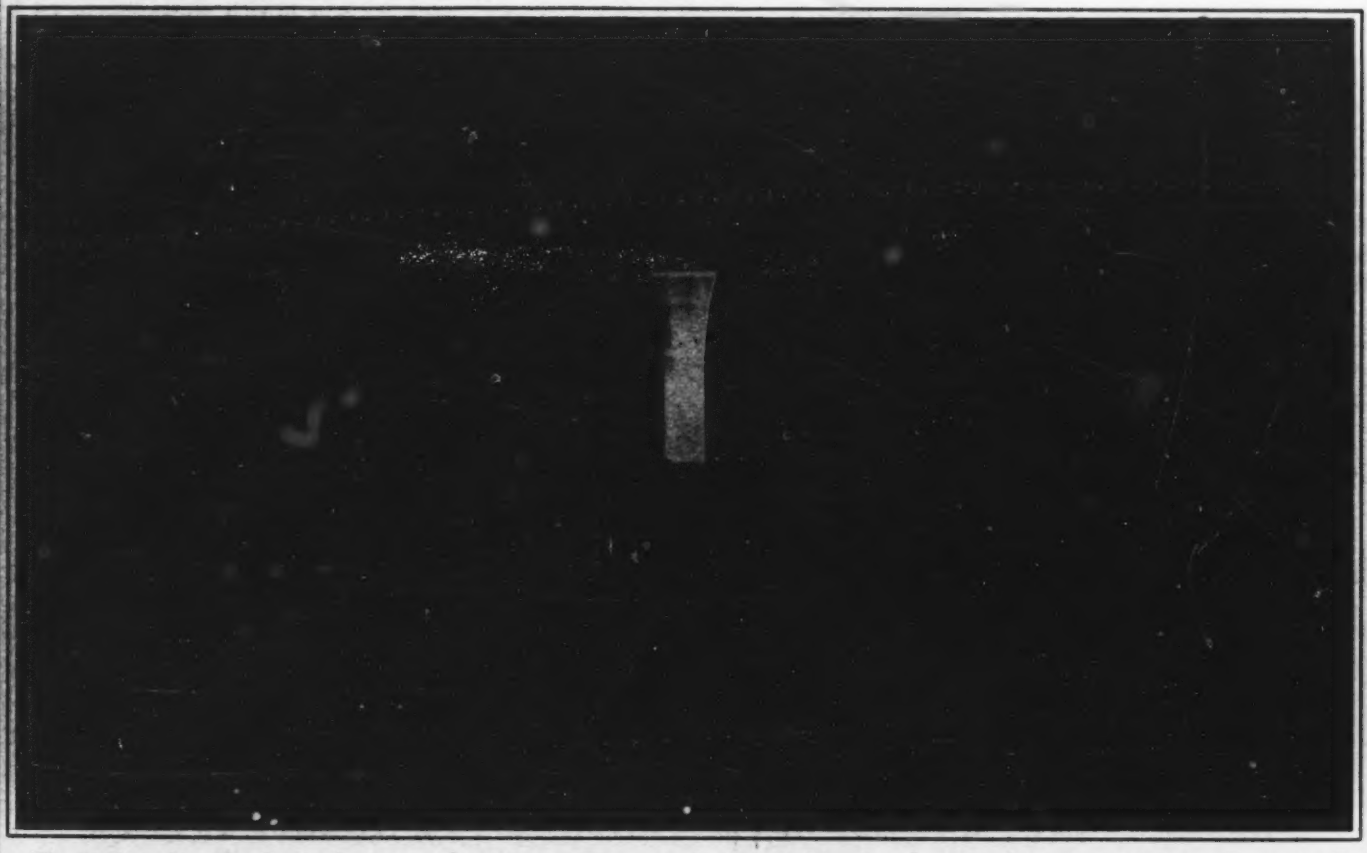
Researchers are also trying to determine the optimum design of highways, interchanges, crash barriers and other road works to insure that sand can skip unimpeded across a roadway without accumulating on either edge and spilling into the path of oncoming traffic. In certain areas of Saudi Arabia, this can easily happen, for example, if the embankment angle is not precisely correct.

The institute also has undertaken some *basic* research in sand dune behavior. One researcher has experimented with modeling sand dune behavior in three dimensions on a computer. Another scientist, Dr. Kwasi Bofah, a Ghanaian who holds a Ph.D. in aeronautics from the California Institute of Technology, conducted experiments for the institute in a wind tunnel at the University of Colorado Fluid Mechanics and Diffusion Laboratory. With the help of German consultants, Bofah also has produced a design for a huge wind tunnel in which sand dune movement could be tested under variable, artificially-induced wind conditions. By tilting the device, says Bofah, studies could be carried out to determine how sedimentation occurs on both the slip-face and up-face sides of a dune. Using such a sand wind tunnel, researchers could actually watch dunes form in a compressed amount of time, and thereby gather information about how they might intervene to control the process. Still on the drawing boards in 1986, the sand dune simulator was awaiting possible funding.

Water pollution – particularly from oil – is another prime concern not just for Saudi Arabia, but for all nations on the Arabian Gulf, one of the world's busiest supertanker shipping lanes.

Addressing the pollution threat, a five-man team in the Water Resources and Environment Division, which in 1986 was the largest of six divisions at the institute, has produced hydrodynamic computer models that predict the likely path of actual and hypothetical oil spills in the Gulf. According to Dr. Huseyin Cekirge, who holds a Ph.D in applied mechanics and mathematics, the model can be used to both forecast where a spill will go from a particular source and trace an oil slick back to its most likely point of origin. Models have been produced for both seasonal tidal currents and storm surges. According to Dr. Cekirge, the models held up remarkably well when tested against data collected from actual spills, including the major 1983 Nowruz spill from offshore Iranian wells. As a result, models developed at the institute are being used by the Gulf Area Oil Companies Mutual Aid Organization, a group dedicated to fighting oil pollution in the region.

The division also has conducted baseline ecological studies of three areas: Tarut Bay, a major shrimp breeding ground close to urban Dammam and the Ras Tanura oil terminal, the northwestern Gulf, an area of oil facilities expansion, and in the Red Sea off Yanbu' Industrial City. The division has developed solid waste management master plans, monitored air pollution using mobile laboratories, and examined strategic plans for kingdomwide water use. The division also has developed an automatic irrigation scheduling scheme in al-Hasa, which, when implemented, could have a dramatic impact on some 22,000 farmers in the oasis by increasing their crop yields without overly depleting ground water resources.



The institute has also focused on corrosion. After several in-depth studies, one, completed in early 1986, it made specific recommendations on how to limit corrosion of pipelines and other facilities at Jubail Industrial City. Another study, conducted jointly by the institute and Battelle Laboratories in the U.S. and completed in 1985, suggested that it is both feasible and practical to cathodically protect oil pipes wrapped in unbonded tape coatings from corrosion, even when they traverse *sabkha*, the salt-laden sandy soil found in much of the oil-rich Eastern Province. In another project affecting the kingdom's oil industry, researchers in 1985 launched a five-year investigation of scaling – the tendency of alkaline earth carbonates and sulfates in oil-well brines to leave hard deposits in both underground well bores and surface pipes. By monitoring the process over time, researchers hope to improve the industry's ability to predict and limit scaling as a costly nuisance in oil field operations.

Not all of the work of the institute involves the natural sciences. The Economics and Industrial Research Division instead concentrates on socioeconomic questions. For example, the division has investigated the impact of domestic gasoline price increases on consumption and has examined exchange rate fluctuations between Gulf nations. It set up an economic data bank for the Saudi economy, produced a statistical handbook on the oil industry and generated a predictive model for national manpower requirements in the non-oil private sector.

In 1986, the wide-ranging work of the Research Institute was supported by a staff of nearly 300, including about 50 researchers hired just for the life of specific projects and some part-time researchers who do double duty on the faculty of UPM. While the number of full-time staffers has increased markedly since 1981, when there were about 150, the institute's manpower has fallen short of its projections.

Nevertheless, the amount of work the institute has taken on, especially client-funded projects, has mushroomed since it was established in 1977. By 1986, close to 60 major studies had been completed for clients ranging from the Gulf Cooperation Council (GCC), to the Saudi-Sudanese Joint Red Sea Commission.

Whether the institute will eventually turn from applied to pure research and join the world's high-powered think tanks is a question Saudi Arabia cannot answer now. For what the kingdom needs – and what the Research Institute hopes to provide – are immediate, practical soloutions for a nation moving headlong down the road to industrialization. In the words of its director, "We are looking to the problems of today."

In Kuwait something very similar – if older – is happening at the Kuwait Institute for Scientific Research (KISR).

Established in 1967, KISR is conducting experiments that its scientists hope will help solve national and regional problems. One high priority project, for example, involves attempts to increase local food production – a difficult task in Kuwait's arid climate. Another involves methods of removing metal and chemical pollutants from millions of gallons of waste water poured by Kuwait's oil refineries into the sea each day.

The scope of this work represents a sub-

stantial change from KISR's modest beginning. Back in 1967, KISR had a total of four scientists and one division, whereas by early 1986 it had 115 scientists and 316 researchers – mostly Arab – and five divisions dealing with food resources, environment and earth sciences, engineering, petroleum, petrochemicals and materials, and techno-economics.

As at UPM, KISR scientists have focused on the ecology of the Arabian Gulf – described by the environmental information agency Earthscan as "one of the world's most fragile seas." The Gulf today must cope with the potentially dangerous input of the world's heaviest concentration of water desalination plants, more than 20 oil refineries and petrochemical, fertilizer and natural gas plants – plus untreated sewage from the burgeoning cities of the Gulf and potential spillage from oil tankers.

Because it is shallow and almost landlocked, these polluting effects last longer in the Gulf than in the open seas; there is no way for the Gulf to flush the pollutants into the Arabian Sea. KISR, therefore, is trying to accumulate data by identifying pollutants – a step towards recommending specific abatement methods.

KISR's interest in the Gulf specifically includes seafood – since fish play an important part in the diet of Kuwaitis and because shrimp constitute Kuwait's second largest natural resource after oil. In 1986, in fact, each five-pound box of Gulf king prawn was bringing more than a barrel of oil on Japanese and American markets; shrimp, moreover, are a renewable resource and thus could still be earning money for Kuwait long after its non-renewable petroleum runs out.

In recent years, however, overfishing, pollution and destruction of coastal breeding grounds – by land reclamation – have drastically reduced the Gulf's shrimp population.

KISR, therefore, has zeroed in on ways to safeguard the seafood industry. Between 1972 and 1979, KISR hatched, reared and released into the gulf over 120 million young shrimps in an effort to re-stock the declining shrimp population, and, in 1980, tried to raise young shrimps to marketable size on land. Although this proved impractical it *did* produce results: on KISR's recommendation, the Kuwait government has now introduced a closed season for shrimp.

In 1986 KISR was concentrating its efforts on fish. The institute built 20 large ponds at al-Khiran in southern Kuwait, where marine scientists were testing different rearing methods; for example, the 'raceway' system: a complex of fast flowing canals in which fish put on weight quickly by constantly swimming against the current – and thus absorbing more food.

Another concern for KISR is energy needs after petroleum resources are exhausted. Accordingly, in 1976, the institute – again, like UPM – launched a solar energy program that has already produced cooling systems to replace air conditioners in greenhouses and homes. KISR has also experimented with a kindergarten in Kuwait city – where solar collectors installed on the roof heated water – and has helped design and build an experimental solar power station to convert the sun's rays into energy for use, primarily, in the distillation of fresh water from the sea.

As millions of gallons of water are produced each day in Kuwait by an

energy-hungry evaporation process, KISR scientists are continuously seeking new power-thrifty desalination methods. Like scientists at the UPM institute, they experimented, for example, with "reverse osmosis," in which ultra-fine filters are used to strain salt from sea water. This process is already being used at desalination plants in Gulf states.

Scientists at KISR also tested the effect of heat, humidity and sand abrasion on imported and locally-produced building materials to determine which ones would be best suited for Kuwait; developed a computerized library management system; and were assessing methods of recycling industrial waste – including thousands of discarded automobiles. In fact, so many experiments were underway at KISR that the institute outgrew its facilities. At one stage, buildings originally designed as garages were being pressed into service as offices at KISR headquarters on the outskirts of Kuwait City, but a new KISR complex with 16,000 square meters of laboratories (172,222 square feet) and 11,500 square meters of office space (123,785 square feet) was inaugurated in February, 1986.

The complex is essential. Since 1973, KISR has increased in size ten fold and now boasts more disciplines than many older institutes in the West. Indeed, its scope is such that it provides Kuwait with a wide range of on-the-spot expertise to help solve general problems, but also enables the institute to set up multi-discipline task forces to tackle specific ones. In 1986, for example, a special task force, comprising metallurgists, electrologists, chemists and engineers, was investigating the chronic problem of sea water corrosion in the cooling processes of local industries; this corrosion costs Kuwait millions of dollars a year.

Originally, most of KISR's research was directed from within, but in the 1980's it had become increasingly responsive to outside needs. By 1986 about 50 percent of the research carried out at KISR was supported by clients through contracts or specific grants. Unfortunately, KISR has discovered, old habits die hard. Thus many Kuwaitis still prefer to call in Western expertise rather than turn to KISR. This is changing slowly. Since many of the problems being tackled by KISR, such as corrosion and desalination, are common to other nations of the Gulf, the institute hopes eventually to establish itself as a regional scientific center.

Institute efforts, in fact, have already produced results. KISR operates one of the few all-Arab crude oil analyzing laboratories, and its Complete Arab Telex (CAT), with simplified keyboards of one character per Arabic letter, is in commercial production for the Arab world.

The little shaikhdom of Kuwait – with a total land area of 19,295 square kilometers (7,332 square miles) – is sprinkled with KISR installations: a marine biology station on the coast at Salmiya, a desalination project at Doha and – a particularly important project in today's ecology-conscious climate – a projected national park on a desert site northwest of Kuwait Bay.

KISR's work, so far, has ranged from the exotic to the historic. In November 1978, for instance, the institute was asked to solve a rush of flying saucer sightings by army officers, policemen and oil company personnel in Kuwait. KISR agreed, launched an investigation and came up with its conclusion: the UFO's were probably reflections of fumes from Kuwait's oil fields. KISR also tried to break the secret vegetation cycle of the desert truffle – so that this expensive wild delicacy, once favored by the pharaohs, could be cultivated at the cost of ordinary mushrooms. None of these problems may equal the theorems developed at the House of Wisdom 10 centuries ago, yet all contribute to what is clearly a revival.

Such institutes as KISR and research center at UPM may be the highlights of Arab science in the modern world, but they – and such other organizations as KACST and CASTARAB – are by no means the only routes by which scientific progress is spreading. Because of the sheer size of its massive five-year development programs, for example, Saudi Arabia at one point had drawn to the kingdom many of the largest and most advanced corporations in the industrialized world – and with them the fruits of their highly sophisticated research and development programs.

The outstanding example of how Saudi Arabia extracts benefits from such corporations is its $3.7 billion Peace Shield air defense and communications project; contracts for the project stipulated that 35 percent of contract values be used to establish *new* joint ventures using advanced technology in partnership with the Saudi private sector. Among the first projects under this Offset Program was a $165 million venture to build an advanced aircraft engine maintenance plant and train Saudis in its technology. Partners in the venture were General Electric, Pratt & Whitney, the Saudi Gulf Establishment, the Saudi National Industrialization Co. and the Gulf Investment Establishment.

In another vital area – petroleum technology – the Saudi government has taken steps to transfer to the kingdom the highly sophisticated know-how and equipment on which geoscientists at the Arabian American Oil Company (Aramco) depend heavily in both the development of established oil and gas fields and the endless search for new reserves.

Until 1983, Aramco had relied heavily on geoscience computing centers outside the kingdom – in Croydon, England, and in the U.S. – where specialized men and machines were available to process the reams of seismic and other data used to answer certain highly complex questions concerning the disposition and likely performance of reservoirs. But since then even this gap in domestic know-how was closed – with the construction of Aramco's Exploration and Petroleum Engineering Center (EXPEC) in Dhahran.

With the kingdom and Aramco engaged in a concerted push to train Saudi nationals to fully operate and manage Saudi Arabia's hydrocarbon industries, EXPEC came not a moment too soon. Together with UPM and its Research Institute, EXPEC helps provide a degree of self-sufficiency.

EXPEC's vanguard project – and, in a sense, its linchpin – was the Computer Center, which came on stream in early 1982 and was later upgraded to include the very latest technology. When His Majesty King Fahd visited Aramco in May 1983 to commemorate the company's 50th anniversary and inaugurate EXPEC, he was told about a very special new computer ordered for the center to aid in the development of the kingdom's oil technology. That computer – the Cray IM-4400 vector processor – can perform 240 million arithmetic operations per second – 10 times faster than any computer in existence.

Getting the computer from its manufacturing site in Chippewa Falls, Wisconsin, to its final resting place at EXPEC was one of the most carefully planned factory-to-desert technology transfers ever undertaken. The 13-stage effort involved a team of 50 people, who had to arrange additional load bearing supports for the 22,000 kilograms (10,000 pounds) of computing equipment installed in the Computer Center. Other special provisions included the installation of a freon refrigeration unit and chilled water heat exchange system to dissipate the excessive heat that such a computer generates. Officially accepted by

Aramco in October 1984, it was the first Cray in the Middle East and in 1986 was one of about 130 in the world, each custom made for its purchaser.

By 1986, the Cray was being used at EXPEC to process certain seismic data and to mathematically simulate the most important large hydro-carbon reservoirs. All other seismic data recorded by Aramco – and previously processed outside the kingdom – was being handled by other new equipment at the center, including IBM's latest large main-frame computer, the 3090-200, which was installed in December 1985. In addition, new three-dimensional simulation models were under development for use in studying some of the world's largest reservoirs.

EXPEC also houses other high-tech equipment: the latest in geologic full-color map plotters, high resolution color graphic stations, laser and microfiche printers and multiple electrostatic plotters. And it contains a computer library of more than 300,000 magnetic tapes.

Meanwhile, in the nearby Laboratories II Building, petroleum chemists and technicians have also begun to employ modern analytical instruments in a wide range of work formerly sent to major labs outside the kingdom. The laboratory provides EXPEC with many clues about reservoir characteristics. By analyzing drilling core samples, scientists are able to measure rock porosity and permeability – keys to the amount of oil in a given reservoir and the rate at which it will flow. From such oil samples, they can also make precise measurements of pressure, volume and temperature relationships in a given reservoir and determine the salinity, sulfur content and grade of crude oils. Trained experts also test chemicals used to stimulate production from balky wells and determine optimum products for drilling muds and cement. All of this information is crucial to Aramco's reservoir and production engineers charged with developing Saudi Arabia's oil and gas reserves in the most efficient way advanced technology will allow.

In the case of the Peace Shield Program and EXPEC, the transfer of technology is direct and the equipment and know-how arrive largely unmodified. But there are areas too in which outside technology has been altered and improved. Aware of the sometimes preposterous and costly consequences of uncritically deciding to import the products of Western technology and then discovering they are inappropriate, Saudi Arabia and other Islamic countries have begun to generate their own solutions to indigenous problems.

The fields of construction engineering and architecture offer even more visible signs that outside technology is being adapted to suit local needs. A rich Islamic tradition has produced extant forms still remarkable for their efficiency, economy, beauty and the extent to which they suit local climatic and social conditions. Examples include the domed roof, the inner courtyard – often with a fountain at its center – and the windcatcher or wind tower, an ancient form of air conditioning. Yet Arab countries, in their first rush toward modernization, ignored their own traditions in favor of the West's.

Since the late 1970's that has begun to change. Jolted by the inappropriate application of Western building forms to the Middle East, a handful of architects have founded a modern movement in Islamic architecture. In some cases, they preserve time-honored forms using traditional techniques; in others, they incorporate new technology in the construction of modern buildings based on traditional forms. These modern Arab or Muslim architects have been educated either in the West or at schools that now exist in Cairo, Baghdad, Beirut, Damascus, Amman, Tunis, Alexandria, Khartoum, Riyadh, Dammam and Aleppo, but their goals are similar: acceptance of modern advances in the engineering sciences without forsaking their own architectural traditions.

Internationally famous Hassan Fathy of Egypt has been the most prominent and persistent voice in this movement for some 45 years. Resurrecting domes, vaulted arches, courtyards, mud-brick construction, and using an approach to modern urbanism that emphasizes Islamic principles of oneness and unity, Fathy has influenced many others working in the Middle East.

One of his younger proteges, for example, Abdel Wahed El Wakil, received the Aga Khan Award for Architecture in 1980 for his Halawa House in Agamy, Egypt, which drew on the talents of a traditional Egyptian master mason named Aladdin Moustafa. El Wakil's award-winning Sulaiman Palace, built on reclaimed land in the prestigious al-Hamra section of Jiddah for a prominent Saudi businessman, combined modern Western amenities with ancient Arab divisions and detailings of space. For the same client, El Wakil designed a commercial headquarters in Jiddah of Datsun Saudi Arabia that houses modern workshops, offices and showrooms in a structure resembling the traditional mud houses of the Central Province of Najd.

Interviewed in the architectural journal *Mimar* in 1981, El Wakil expressed a view shared by many Muslim architects: "You cannot dissociate work from belief. If you take Islam as a way of life, of which Islamic architecture is a part, a man's work is his mission on earth."

The late Fazlur Khan, a Muslim originally from Pakistan who worked many years in the U.S. for the architectural and design firm of Skidmore, Owings and Merrill, applied this philosophy to the construction of buildings in the Middle East. His structures are both well-suited to the area and highly dependent on Western technology.

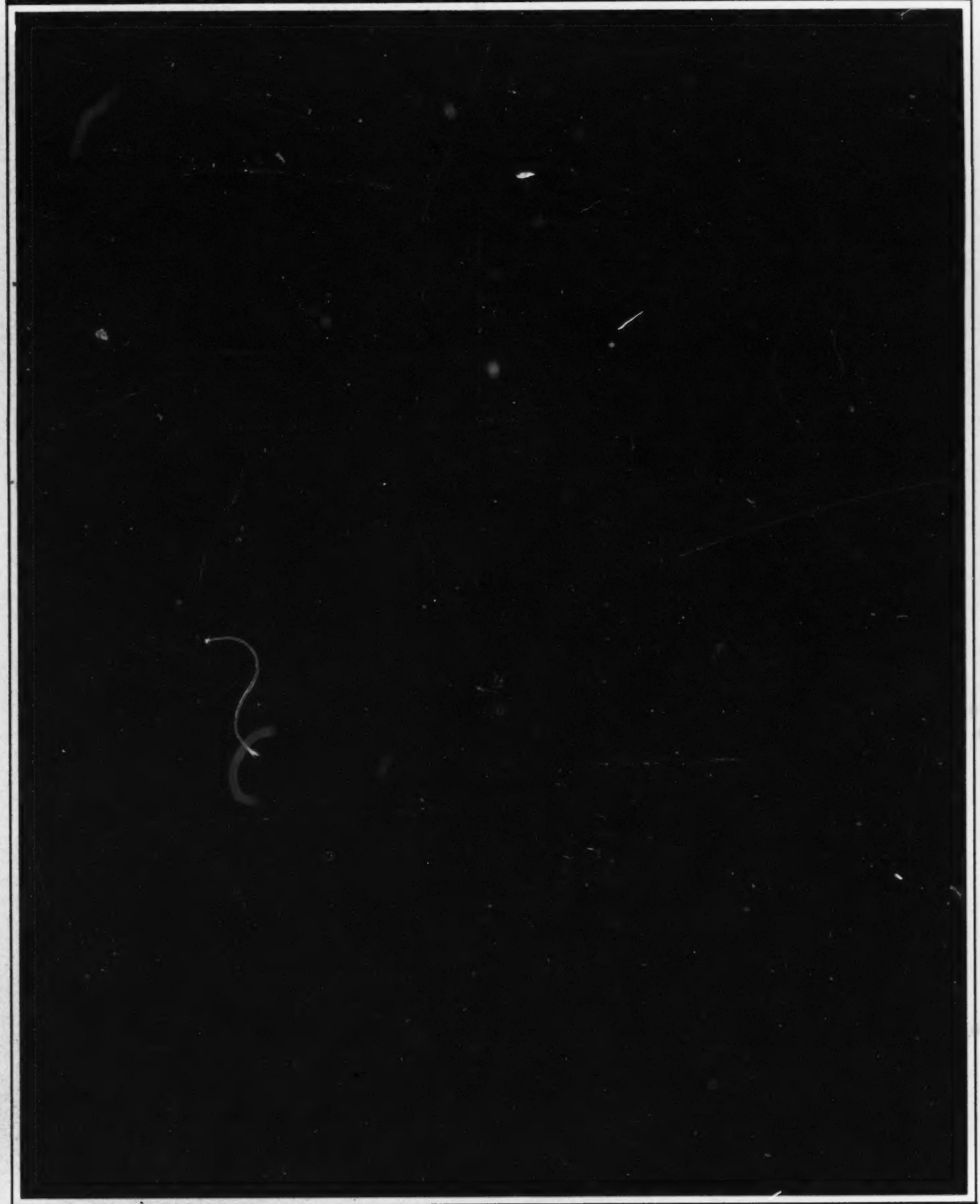
A notable example of this is the roof design for the *Hajj* or pilgrimage terminal at King Abdulaziz International Airport in Jiddah, in which Khan played a major role. The roof is actually a system of 210 separate, suspended tents – a modern version of the traditional desert dwelling – using a high-technology Teflon-coated fiberglass fiber (See *Aramco World*, July-August 1981).

Interviewed by *Aramco World* shortly before his death in 1982, Khan commented on the importance of a knowledge of Islamic tradition when designing modern structures: "In 1976, I made the Hajj myself, so I have direct familiarity with this Islamic rite. In designing the terminal to receive incoming pilgrims, we wanted to create an environment similar to that at the plain of Arafat."

Khan continued, "Western technology creates a great temptation to take it without transformation which makes structures quickly irrelevant. By transformation, I mean adapting Western technology to the sociological and climatic conditions of the people who will use or live in the buildings created from it. It doesn't make sense, for example, to build all these glass boxes in the desert for a people who, over hundreds of years, have developed their own traditional forms."

This transformation of technology is in many ways the key to any scientific resurgence among the peoples of Islam, since it is only when technology is adapted by those who use it that genuine scientific inquiry can take root and original experimentation can flourish. And while international gatherings on the topic of science, technology and development are important, it is, in Zahlan's words, "the collective commitment to the joy of learning and scientific discovery" that ultimately will determine the degree to which scientific work can advance in the Islamic East.

All these examples – of research and development, of vital transfers of technology, of scientific experiments in applied fields – suggest the level of science and technology in the Middle East today, and the extent of the commitment that some Muslim countries have made. As in the past, when farsighted caliphs sponsored and supported the scholars who made the Golden Age possible, enlightened leaders today are providing generous patronage of scientists – and potential scientists. Together with the recent expansion in research and development such a commitment could yet produce a resurgence in Islamic science worthy of its historic antecedents. ■



ARABS AND ASTRONOMY

WRITTEN BY PAUL LUNDE – WITH ZAYN BILKADI
ILLUSTRATED BY MICHAEL GRIMSDALE

In 1985, aboard the space shuttle *Discovery*, Saudi Arabia's Prince Sultan ibn Salman ibn 'Abd al-'Aziz Al Sa'ud, the first Arab in space, helped launch the Arab world's second communications satellite, photographed the Arabian peninsula and made precise lunar observations.

To scientists in Islam's Golden Age – whose bold thoughts laid the groundwork for today's exploration of space – the satellite might have been astonishing, but the Prince's photographic assignment and his other assignments would not have been totally unfamiliar. They too were knowledgeable about optics and astonomy and they were experts in ephemerides – tables showing the positions of celestial bodies on given dates.

Lunar observation, for example, was, and is, important to Muslims; for religious purposes they follow a lunar calendar and the new moon marks the beginning and end of the fast of Ramadan and determines the date of the pilgrimage to Makkah (Mecca) – the Hajj – two of the five religious duties incumbent upon all Muslims.

Celestial mapping also sprang from a religious concern: the need to establish correct coordinates of cities so that Muslims could determine the direction of Makkah – the *qibla* – towards which all Muslims prostrate themselves in prayer five times a day. And though observation of the new moon and determination of the *qibla* may seem prosaic subjects today, it was by pondering just such everyday phenomena that advances in science were made.

The mathematical determination of the *qibla*, for example, was one of the most advanced problems in spherical astronomy faced by medieval astronomers and mathematicians and the trigonometric solution eventually found was of great sophistication. Trigonometry itself, largely an Arab development, is fundamental to the computation of planetary orbits as well as to terrestrial mapping, and consequently medieval *qibla* tables often attained great accuracy. That of al-Khalili, who wrote in Syria in the 14th century, gives the coordinates of a large number of towns in degrees and minutes and is generally accurate to within one or two *minutes*.

It could be argued, in fact, that precise observation and an ability to find new mathematical solutions to old problems were the two main strengths of Muslim scientists in the Middle Ages. And though they, like their European counterparts, never fully escaped the tyranny of Aristotle and Ptolemy – whose models of terrestrial geography and of the heavens dominated men's minds until the Renaissance and were not finally demolished until the publication of Newton's *Principia* in 1687 – Muslim scientists were the first to express doubts about many of the details of the Ptolemaic system. Indeed, it was the growing awareness of the divide between Ptolemy's theoretical model of the universe and observed reality that culminated in the discoveries of Nicolaus Copernicus, Tycho Brahe and Johannes Kepler during the 15th to 17th centuries, and some of those doubts had been transmitted to European scientists from Spain in 12th- and 13th-century translations of Arabic scientific works.

Al-Battani, called by his European translators Albategni, is a case in point. He wrote in the ninth century on a wide number of scientific topics and some of his observations struck at cherished Ptolemaic dogmas. He showed, for example that, contrary to Ptolemy, annular eclipses – in which a ring of light encircles the eclipsed portion – were possible, and that the angular diameter of the sun was subject to variation. He showed – again contrary to Ptolemy – that the solar apogee was subject to the precession of the equinoxes; he corrected a number of planetary orbits; he determined the true and mean orbit of the sun. Interestingly, in the light of Prince Sultan's observation of the new moon, al-Battani also developed a theory of the conditions of visibility of the new moon.

Other Muslim astronomers also came up with data that conflicted with Ptolemy, one of them perhaps the greatest Muslim physicist of them all: Ibn al-Haytham, called Alhazen in the medieval West. Al-Haytham argued that the Milky Way was quite far from the earth no matter what Aristotle said, and estimated the height of the earth's atmosphere at 52,000 paces – a pace being roughly one meter, or three feet. Al-Haytham worked that out from his observation that the astronomic twilight begins when the negative height of the sun reaches 19 degrees. Since the atmosphere is about 50 kilometers up (31 miles) and 52,000 paces is roughly 52 kilometers (32 miles), Ibn al-Haytham was very close indeed.

In the pre-telescope age, observational astronomy was, of course, carried out with the naked eye. Muslim scientists, however, perfected observatories in a number of places; those at Maragha and Samarkand are the most famous. At these observatories, astronomers gathered to refine Ptolemy's coordinates for the stars and, eventually, to revise Ptolemy's catalog of stars. This catalog which gave the positions of 1,022 stars, classified, as they are today, by magnitude, or brightness,

was heavily revised, notably by the 10th-century astronomer Abd al-Rahman al-Sufi, whose *Book of the Fixed Stars* is the earliest illustrated astronomical manuscript known; the copy in the Bodleian Library, the work of the author's son, is dated 1009 and the author expressly states that he traced the drawings from a celestial globe.

There is an even earlier representation of the heavens in an Umayyad hunting lodge built about A.D. 715 in Jordan. It is called Qasr al-'Amra (See *Aramco World*, September-October 1968; July-August 1980) and in the dome of the bath house in the lodge are fragments of a fresco showing some 400 stars and parts of 37 constellations, drawn on a stereographic projection – which implies a familiarity, even at that early date, with Ptolemy's *Planispherium*.

Arabs also excelled at making astronomical instruments – particularly astrolabes which were used for navigational purposes, for determining the positions of stars and for solving problems in spherical astronomy. There were three sorts of astrolabes: planispheric, linear and spherical. These were used at the observatories of Maragha and Samarkand, and were substantially the same as the instruments used by European astronomers until the invention of the telescope.

The observatory at Maragha was founded by the famous mathematician Nasir al-Din al-Tusi in 1259, one year after the fall of Baghdad to the Mongols. Because the Mongol invasions into the lands of Islam had opened a land route to China, Muslim astronomers were eventually able to work together with their Chinese counterparts.

The main theoretical work done at the observatory had to do with simplifying the Ptolemaic model and bringing it into line with the Aristotelian model, which postulated uniform circular orbits for the planets. Although they were often misguided, they made very important contributions; Ibn al-Shatir, for example, came up with models of the movement of the moon and of Mercury that are strikingly similar to those of Copernicus.

The observatory of Ulugh Beg at Samarkand, built between 1420 and 1437, (See *Aramco World*, January-February 1976; July-August 1984) was used to re-compute the positions of the stars in Ptolemy's catalog, and there is little doubt that the organization of this observatory and the instruments employed there influenced Tycho Brahe's famous observatories at Uraniborg and Stjerneborg.

Another observatory thought to have influenced Tycho Brahe was that proposed and built in Istanbul in the 16th century. In 1571 in Istanbul, Taqi al-Din Mohammed ibn Ma'ruf, a former judge from Egypt and author of several books on astronomy, was appointed head-astronomer of the Ottoman Empire and immediately proposed construction of an observatory. He wanted to begin the urgent task of updating the old astronomical tables describing the motion of the planets, the sun and the moon. His request was well received by the Grand Vizier and patron of sciences, Sokullu

Muhammad, but between 1571 and 1574 the Ottomans had to fight no less than three costly wars against the three major powers of Europe, Venice, Spain and Portugal, so it was not until mid-1577 that the project was completed. Taqi al-Din's observatory consisted of two magnificent buildings, perched high on a hill overlooking the European section of Istanbul and offering an unobstructed view of the night sky. Much like a modern institution, the main building was reserved for the library and the living quarters of the technical staff, while the smaller building housed an impressive collection of instruments built by Taqi al-Din himself – including a giant armillary sphere and a mechanical clock for measuring the position and speed of the planets; aware that Europe was beginning to move ahead in astronomy he was determined to restore the Islamic world's once uncontested supremacy.

A few months later, unfortunately, on a cold November night – the first night of the holy month of Ramadan – a comet with an enormous tail unexpectedly edged into sight and set off a controversy that would put an end to his dream – and the observatory. Twisting and twirling, the comet grew brighter and steadier by the day for 40 days, and soon became a fireball soaring in the heavens like the sun and terrifying observers on earth.

One such observer was the Sultan, Murad III, whose own father, Sultan Selim, had died shortly after another comet had appeared. About to open a campaign in the Caucasus aginst Persia and its allies, Murad demanded a prognostication on the comet and Taqi al-Din, working day and night without food and rest, did so. He noted first that both the tail and head of the comet seemed to point east towards Persia – as if, he thought, to discharge their ominous fire there. He also noted that the comet appeared first in the house of Sagittarius, symbolizing , he decided, the Ottoman archer, and that it would disappear in Aquarius, a sign of peace and plenty awaiting the archer. Thus persuaded that such phenomena were undeniable signs of good fortune for the Ottomans, and confident in the accuracy of his observations in regard to the path of the comet, Taqi al-Din requested an audience with the Sultan and announced that:

There are joyful tidings for you concerning the conquest of Persia, for the foe is lying, with failing breath, upon the ground.

The appearance of such a sublime flame
Is for this realm an indication of well-being and splendor,

But for Persia it is a bolt of misfortune.

Unfortunately for Taqi al-Din, his predictions didn't quite turn out right. Though two Persian armies were defeated in the war, the Ottomans experienced certain reverses, a devastating plague broke out in some parts of the empire and several important persons died, and within a short period of time the Ottoman court began to

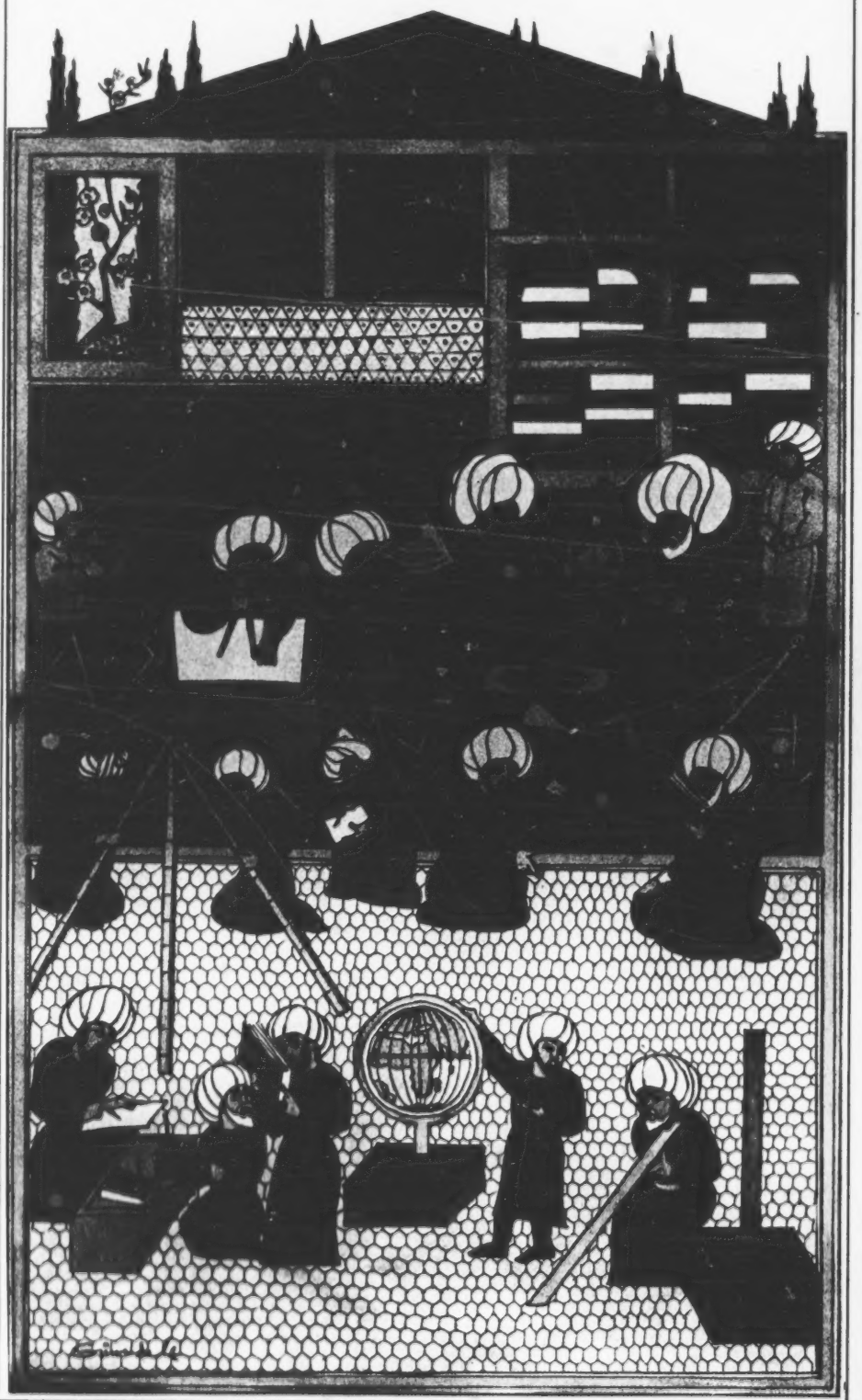
quarrel about the observatory. One faction, headed by the Grand Vizier Sokullu, favored continued support of the institution, and the other, led by Sokullu's political rival, said that prying into the secrets of the future was not only beyond man's power but was also a waste of funds.

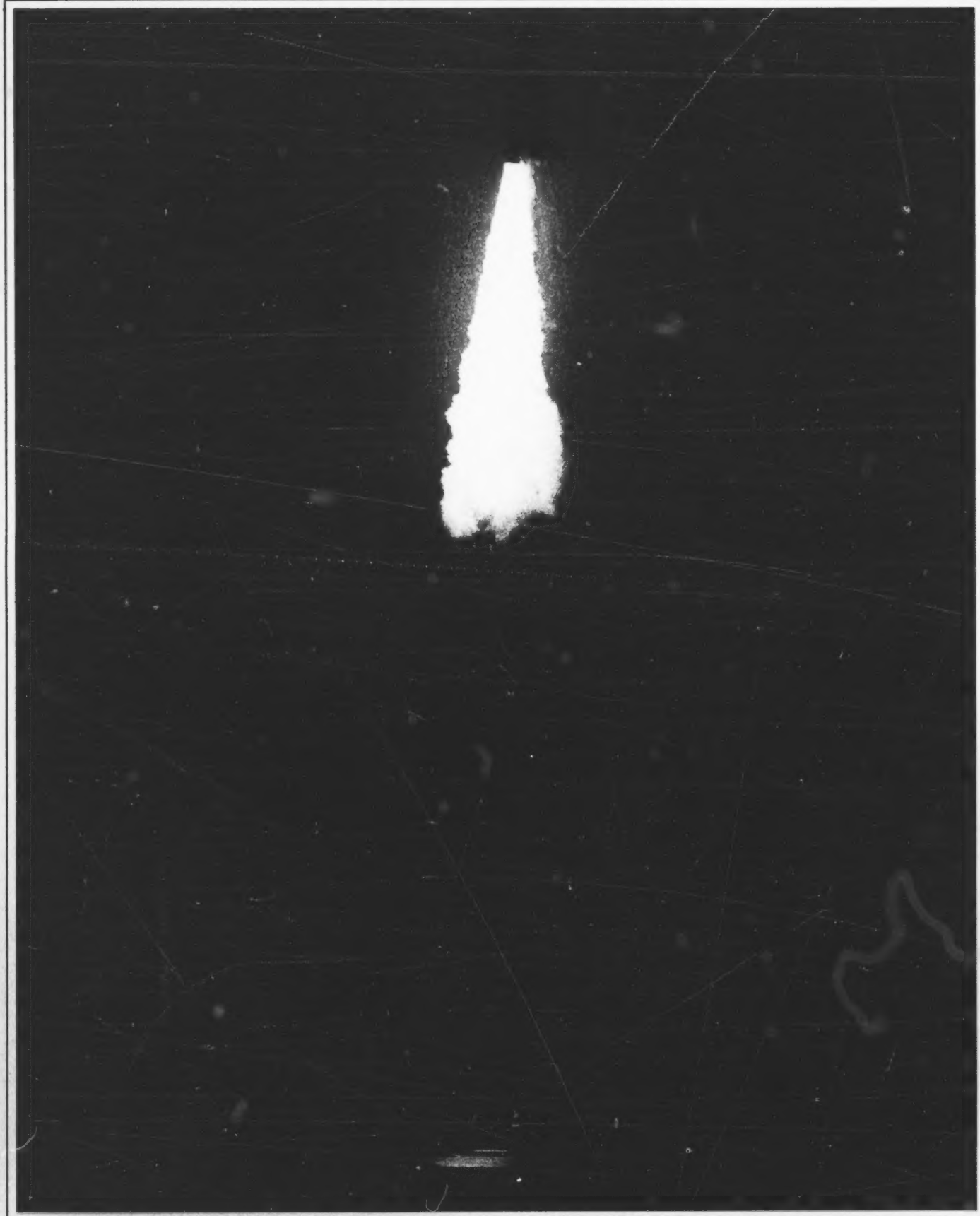
For a short period Sokullu prevailed and Taqi al-Din plunged into astronomy at a feverish pace for two years. But then Sokullu was killed and in 1580 a wrecking squad from the Marine Ordnance Division appeared on the premises, and its commander, citing the misfortunes that had befallen the Ottomans since the apparition of the comet, gave orders to level the buildings.

Another subject allied to astronomy that deeply interested Muslim scientists – and to which they made important contributions – was optics. Thus Newton's *Optics*, published in 1704, had a long history of experimentation behind it. Classical theories of vision held that sight was the result of rays emanated from the eyes, rather than the reflection of light from the object viewed. It was Ibn al-Haytham who broke with this classical theory and developed a theory, with mathematical proof, in accord with the facts. His work with the *camera obscura* and discovery of the mathematical principles behind the phenomenon of the rainbow were important steps in the development of optical instruments – though an explanation of the colors of the rainbow had to wait for Newton.

Other Muslim scientists also made important contributions to this subject, including the famous al-Biruni. One of the scientists connected with the Maragha observatory, Kamal al-Din al-Farisi, wrote an important commentary on Ibn al-Haytham's work on optics, in which he gives the results of a fascinating series of experiments with the *camera obscura*.

Men like these would have been fascinated at the idea of photographing the earth from outer space, and with the theories that make such achievements possible – theories that are in some cases based on observations they themselves originated. It is thus peculiarly fitting that an Arab Muslim should take part in a scientific mission in the heavens that so interested and perplexed the scientists of the Middle Ages to whom we all owe so much. ■





SCIENCE IN THE SPACE AGE

WRITTEN BY THE ARAMCO WORLD STAFF – WITH YASAR DURRA, JOHN CHRISTIE, DOUGLAS A. BOYD, PATRICIA MOODY, KENNETH STOREY, JOSEPH FITCHETT AND ARTHUR CLARK.

PHOTOGRAPHS BY THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA); WORLDWIDE TELEVISION NEWS (WTN); BURNETT H. MOODY; AEROSPATIALE; P. SOUZA, THE ASSOCIATED PRESS; AND JULIAN NIEMAN, SUSAN GRIGGS AGENCY.

When Prince Sultan ibn Salman ibn 'Abd al-'Aziz Al Sa'ud became the first Muslim, the first Arab and the first prince to go into space – in June, 1985 – he also became a symbol of the resurgence of scientific inquiry in the Muslim world and the embodiment of a scientific spirit that was once a hallmark of Islam.

Prince Sultan's voyage to space – in the space shuttle *Discovery* – was not the first manifestation of the Arab world's newly revived interest in space. Four months earlier, on February 8, a great Ariane rocket had soared into the skies over French Guiana. The rocket carried Arabsat-A, the Arab world's first communications satellite and part of a space network that by early 1986 had begun to transform communications throughout the 22 Arab League countries whose leaders and scientists had joined forces to create the network.

But Prince Sultan, by participating in Mission 51-G, and by conducting Arab-organized experiments, was doing something more than reaching space. He was also celebrating Arab mastery of the key scientific disciplines that launched and brought the *Discovery* back: mathematics and astronomy, the "exact" sciences which the Muslim world preserved, enlarged and passed on to the West. And in carrying out in-cabin experiments assigned to him by Saudi Arab scientists, he was also evoking memories of Islamic science in the medieval period.

Over the centuries, it is true, science in the Arab world has declined, but Prince Sultan's experiments suggest the efforts to catch up again now being made in such countries as Saudi Arabia. Prepared by a team of scientists led by Dr. Abdallah Dabbagh of the Research Institute of the University of Petroleum and Minerals (UPM) in Dhahran, they included lunar and earth observations, the recording of data on oil and water in space that might provide helpful information on pollution and oil recovery, and an ionized gas experiment designed by another member of the Saudi royal family. Prince Turki ibn Sa'ud ibn Muhammad Al Sa'ud proposed the ionized gas experiment as part of his Ph.D. dissertation at Stanford University, and Prince Sultan recorded it through the front

windows of the orbiter, using television cameras housed in the bay of the shuttle, for study and analysis by Arab scientists. The prince also used a specially modified Hasselblad 500 EL/M camera to photograph swaths of the Arabian Peninsula for comparison with previous remote sensing images in efforts to develop a groundwater program and to track the movement of sand across the peninsula.

To conduct the oil-water experiment, Prince Sultan had to follow a detailed list of 23 specific steps in order to record reactions when oil and water were mixed in zero-gravity – this time using a 35-mm camera with a zoom lens. When comparisons of the results were made with the findings of similar experiments on earth, they provided a measure of helpful information to research into methods of combatting oil spills and oil recovery.

Prince Sultan also made a first-time-ever observation that excited the entire Muslim world: he sighted – and photographed – the lunar crescent of the new moon through the shuttle window; this sighting, on earth, marks the official end of Ramadan, the fasting period for all Muslims, and the start of the joyful 'Id al Fitr holiday.

All the experiments were the responsibility of a 16-man Arabsat Scientific Experiments Team under Dr. Dabbagh. Working together, these scientists outlined the experiments, trained Prince Sultan and his backup, Major 'Abd al-Mohsin Hammad al-Bassam, in the proper procedures and subsequently analyzed the findings in the kingdom's state-of-the-art laboratories.

Interestingly, these laboratories – particularly those at the Research Institute of UPM – already had the sophisticated research equipment needed to analyze the data returned from Mission 51-G. One example is the Image Processing Center (IPC) of the Research Institute. In operation since 1982, this center, the most sophisticated facility in the Arab world, can process and analyze remote sensing data from aircraft, space shuttles, and other satellites in orbit.

In such Research Institute projects as tracking oil spills, mineral and water exploration, agricultural monitoring, documenting urban growth and controlling sand movement, the IPC has proven invaluable.

It was logical, therefore, that the team of scientists who managed the Mission 51-G experiments included members from four

divisions at the UPM Research Institute: Energy Resources, Economics and Industrial Research, Petroleum and Gas Technology and Geology and Minerals.

Also included were a member of the medical faculty at King Faisal University in Dammam and the chief geologist at the kingdom's Ministry for Mineral Resources in Jiddah. Various ministries and other clients expressed interest in the enhanced photographs taken from space, another reason why UPM's Research Institute was well qualified to handle the project: it has experience in client-funded research.

For Arab scientists, with their proud memories of the Golden Age and the House of Wisdom, the opportunity of working at the leading edge of science is an exciting challenge.

"The Arab world," said Prince Sultan, "is at a turning point. We have gone through the phases of oil, money and early technological development. The new generation is looking forward to joining the rest of the world by obtaining the most important things in that turnaround: opportunity and education. Together they are the keys that open the door for our future. My space flight is just a crack in that door."

The experiments, of course, were only part of the mission. The prince's first job was to supervise the launching of Arabsat-B – the *second* Arab communications satellite. He also participated in a French-organized experiment to measure the effects of weightlessness on the human body; gave a guided tour of the space shuttle's interior in Arabic, which was beamed back to Arab television viewers on earth, and took part in a press conference in space.

A 28-year-old graduate of the University of Denver – with a degree in mass communications – and a trained pilot, Prince Sultan was picked after a search of several months; the Arabsat organization was permitted to select a payload specialist to travel aboard *Discovery* and Saudi Arabia won the slot.

Though payload specialists are not involved in the launch or operation of the space shuttle, their training schedule is still intense: 114 hours of what the National Aeronautics and Space Administration (NASA) calls "habit-ability" training, or – in layman's language – learning to adapt to the routines of daily life in a space shuttle plus learning to handle general housekeeping chores in the confines of the crew's compartment – prompting Prince Sultan to describe the voyage as "a high-tech camping trip."

The training paid off. On the second day of the flight, Arabsat-B was successfully deployed in space 35,900 kilometers above the equator, (22,300 miles) and in 1986 took over the functions of Arabsat-A.

On earth at that time, excitement had reached staggering proportions in the Arabian Gulf region. Between June 17 and June 24, 1985, hours of live telecasting from the Cape Canaveral launch pad and Houston's Mission Control – plus daily Washington updates – kept millions of Arabs glued to their television sets. According to Worldwide Television News (WTN), an estimated 10 million people in the Gulf and Saudi Arabia were tuned in. WTN, incidentally, itself almost at once benefited from the Arabsat satellites; during the 1986 crisis in South Yemen, WTN was able to pick up coverage via Arabsat and re-transmit it to the world.

Interest was by no means limited to Saudi Arabia and the Gulf. Lured by the fact that a tall, darkly handsome jet pilot

was to be the first Muslim in space, millions in Europe, Asia, Africa and Latin America eagerly followed the progress of Mission 51-G on television and in print. This was true even in the United States where space flights had become almost routine; because a prince was on board, the flight of the *Discovery* created a wave of fresh interest in space travel that would, sadly, continue through the tragic in-flight explosion of the *Challenger* in January, 1986. And even then Prince Sultan and Major al-Bassam, now a lieutenant-colonel, played roles; at the request of King Fahd, the two Saudi astronauts, who had met and trained with the seven astronauts killed in the explosion, flew back to Houston to personally convey the kingdom's condolences to the bereaved families.

During the *Discovery* flight, in fact, the U.S. media repeatedly focused on the prince. ABC-Television, calling the prince the "real celebrity" of the flight, showed a film of him talking from space to King Fahd in Riyadh, and Sandy Gilmore of CBS, *USA Today*, America's nationwide daily newspaper, and the prestigious *New York Times* all featured the prince's activities in space.

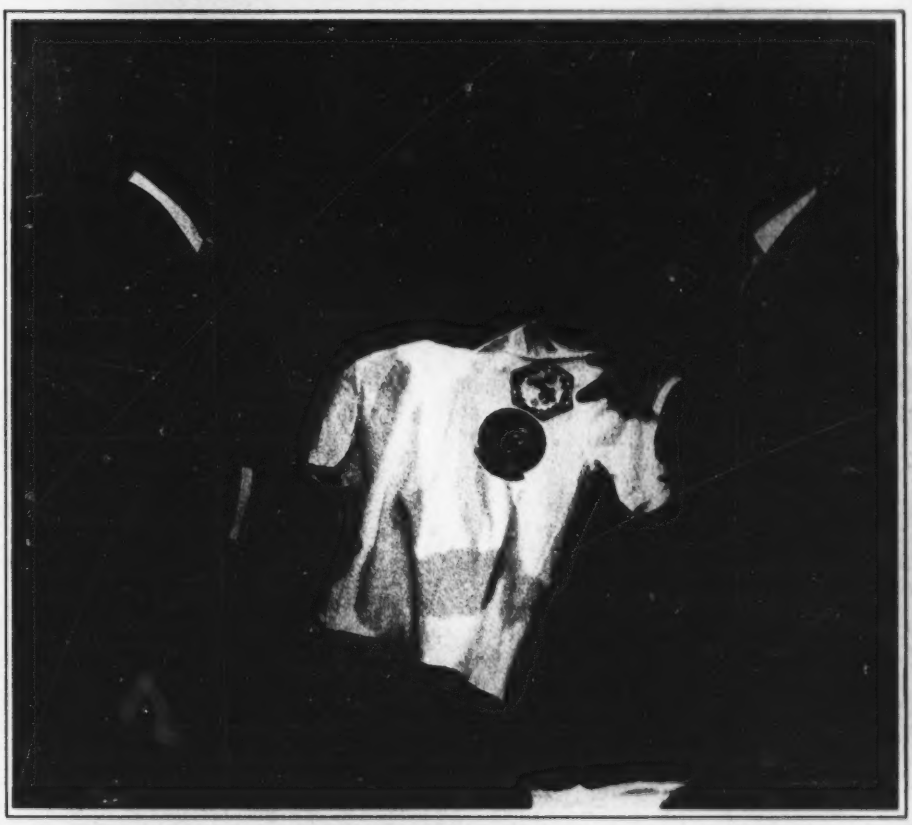
Important international personalities echoed the TV commentators and newspaper columnists. In London, Jonathan Aitken, a British member of parliament, said the prince's involvement in the space program was a "historical step" forward for Saudi Arabia. In New York, Clovis Maksoud, Arab League ambassador to the United Nations, said: "The flight is a symbol of the resilience of our people and the determination of the Arab people to cope with the latest scientific challenges." And in Cambridge, Massachusetts, Dr. Farouk El-Baz, the first Arab to participate in the American Space Program (See *Aramco World*, November-December 1976), predicted that it would "cause a revolution in the thinking of the Arab youth..."

Even when the prince returned to earth the excitement continued. In Saudi Arabia itself, the prince, a nephew of King Fahd and a grandson of King 'Abd al-'Aziz ibn Sa'ud, founder of the modern kingdom of Saudi Arabia, received what the Associated Press described as a "hero's welcome across the kingdom": a seemingly endless series of "processions and motorcades, flying flags and festive decorations, singing and dancing, poetry reading, gifts, awards and commendations," as an embassy newsletter in Washington, D.C., described it. His welcome, indeed, was not unlike the ticker-tape receptions accorded Lindbergh on his return to the U.S. after he flew the Atlantic nearly 60 years before.

At the airport in Taif, Prince Sultan was met by his uncle, the king, was awarded the Order of King 'Abd al-'Aziz and was promoted to major in the Royal Air Force. To mark the occasion, the government issued two new stamps. One, a 20-*halala* stamp, showed the space shuttle, a satellite, a minaret and the official emblem of the Saudi government. The other, a 115-*halala* stamp, showed the shuttle on one side and a NASA emblem on the other,

with the names of all the astronauts that went up in the *Discovery*.

In late 1985, Prince Sultan, setting off on an international good will tour, was also inducted – with five other astronauts, including France's astronaut on Mission 51-G, Patrick Baudry – into the prestigious Legion of Honor. Established by Napoleon, the legion's famous medal is the highest honor that France can bestow, and in a special gesture for the occasion it was awarded to Prince Sultan and the other astronauts by Prime Minister Laurent Fabius personally. In a colorful ceremony, with television lights glinting off the swords of an elegant French Honor Guard, Prime Minister Fabius also appealed for peace in space. "If there is one domain where international cooperation should exist," he said, "it's space, because space is the future and we want it to be a peaceful one for mankind."



Becoming an astronaut, and getting into space, Prince Sultan told an *Aramco World* reporter in Paris, was tremendously important – especially to young people in Saudi Arabia. "I think it showed them that space, like the rest of high technology, is not the exclusive hunting ground of the West and that – literally – not even the sky is the limit any more."

From Paris, Prince Sultan went on to visit Cannes, Tours, Bordeaux and Toulouse – heart of the French aerospace industry – before flying off to the United States for another round of appearances and interviews during a four-city, five-day good will tour, much of it arranged by the National Association of Arab Americans (NAAA).

In Boston, Prince Sultan delivered a moving address focused on the links between the United States and the Islamic world. "When I went up, I...represented 800 (million) to a billion Muslims, and I...took all of them with me to space in an American space ship," he said.

From Boston, Prince Sultan flew to National Airport in Washington, D.C. and later met President Reagan in the Roosevelt Room in the White House; he gave the president an astrolabe, an ancient navigational instrument, some T-shirts commemorating Mission 51-G and a flight jacket with the Saudi flag sewn on it.

Prince Sultan's achievements were a triumph for him personally, of course, but also for Saudi Arabia and the Arab world

as a whole. As one writer said on seeing Prince Sultan talking to King Fahd from space, the people of Saudi Arabia suddenly realized that the kingdom *had* been developing, in the prince's words, "at 2000 miles an hour."

To Prince Sultan, however, the flight into space, the medals and the honors were just a prelude. Now, he said, the job is to utilize the system he helped launch.

Overall responsibility for that system is in the hands of the Arab Satellite Communications Organization. Arabsat, as the organization as well as its satellites are known, was set up by the Arab League in 1976 and is headquartered in Saudi Arabia.

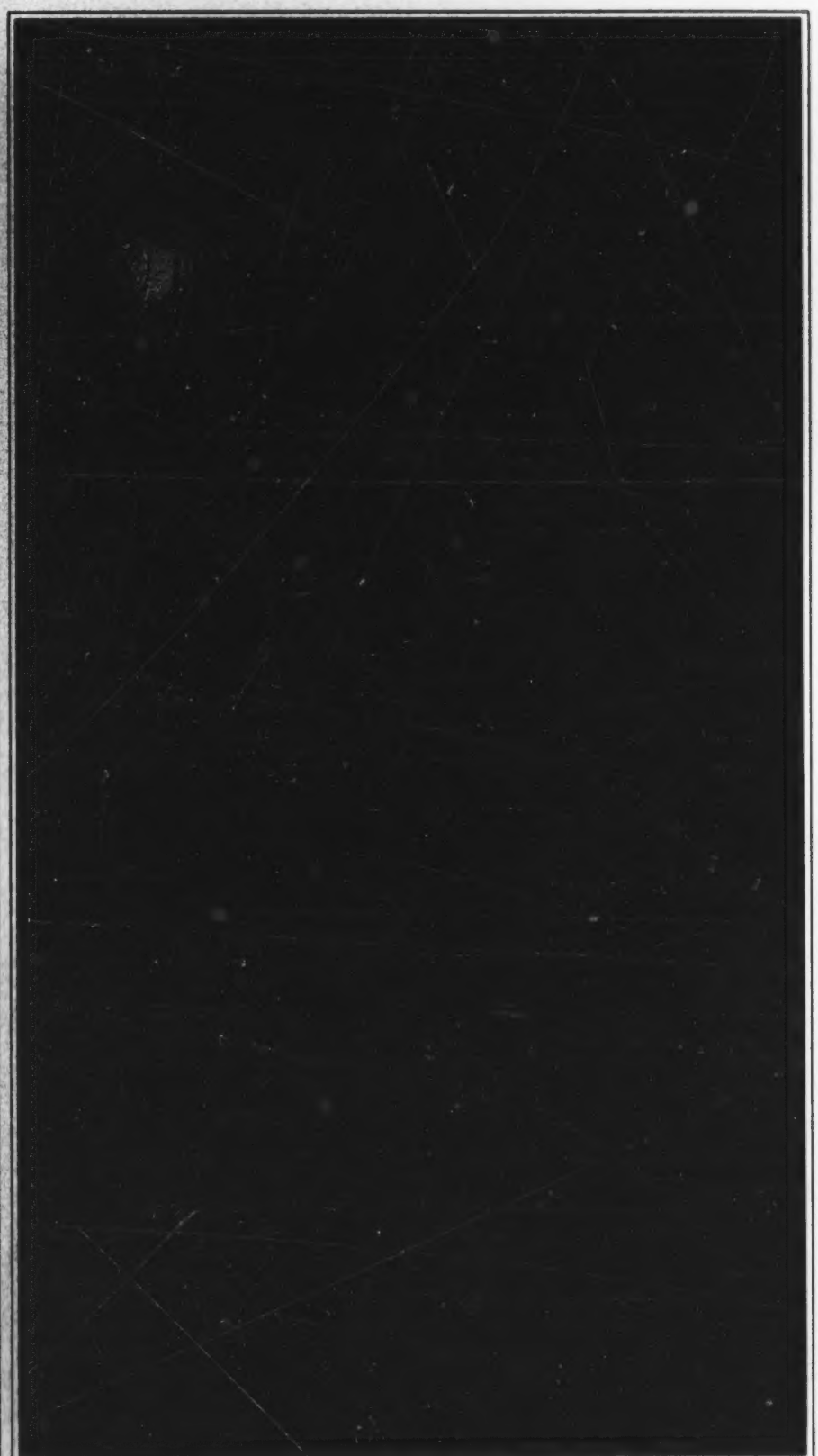
The Arabsat satellites weigh approximately 1,200 kilograms (2,640 pounds), and have two solar-drive assemblies with a wing span of 20.7 meters (68 feet) and 20,000 solar cells to provide energy. Medium size, multi-mission satellites, they are the first of a new generation of regional telecommunications satellites, capable of relaying signals to remote regions of the Arab world previously unreachable by existing international satellites. These signals are picked up by small ground antennae in rural and desert areas, and in metropolitan areas by ground stations with large antennae: 11 meters in diameter (36 feet). Such equipment can handle heavy trunk-route telephone traffic and can originate and receive television transmissions.

Other urban ground stations, employing antennae of the same diameter, can serve smaller cities. In addition, mobile ground stations using antennae 1.6 meters in diameter (five feet) can be used for emergency communications and for community television, what is called "downlink reception" can be provided by small, receive-only ground stations with antennae three meters in diameter (10 feet).

Arabsat's ground-control network – consisting of a satellite control center (SCC), where orbit-injection operations are carried out – monitors satellites and controls them throughout their lifetime, while the primary telemetry, telecommand and control ground station (TTC) maintains permanent contact with both the SCC, via micro-wave links, and with the satellite via large transmitting and receiving antennae. Both stations are located in the Riyadh area, with a secondary TTC in Tunis; this station can temporarily replace the facilities in Riyadh.

Already the Arabsat organization has achieved what Abdullah Shakroun, secretary general of the Arab States Broadcasting Union (ASBU), called a "quantum leap..." in intra-Arab communications. By early 1986, more than half of the Arab world's national TV networks were linked via Arabsat and officials predicted that *all* Arab League states – 22 – would be connected by the end of 1986. During 1985, in fact, 14 countries – Algeria, Bahrain, Djibouti, Jordan, Kuwait, Libya and Mauritania, Morocco, North Yemen, Oman, Qatar, Tunis, the United Arab Emirates and Saudi Arabia – were exchanging almost-daily news items and once-weekly feature programs via Arabsat. And on October 1, 1985 as editors in Tunis were preparing the first-ever Arabsat news package – Israeli jets bombed the Palestine Liberation Organization (PLO) headquarters in Tunis. That was the first item to go out on the Arabsat news exchange. Thanks to satellite transmissions, Arab countries can also send news to the West. Dubai, in fact, started sending its daily television newscast to London by Intelsat in 1986; the transmission was being picked up by a cable network and fed into hotels in London's West End for Arab guests.

Weekly feature program exchanges began on November 11, 1985. Entitled "An Arab Evening" and lasting two hours in all, they included a full-length feature from one of the participating national TV networks plus an educational program prepared by the Arab League Educational, Cultural and Scientific Organization (ALECSO). The first programs aired so far have included prize-winning plays from Iraq and Qatar, footage of the annual Jerash Festival in Jordan (See *Aramco*



World, January-February 1984), a film on Tunisian folklore and – a particularly well-received program – the impressions of a Syrian doctor, now living in the United States, on her return to the place where she grew up.

Arab broadcasting executives reported in 1986 that there was tremendous audience interest in the news items and feature programs being exchanged. Significantly, countries at the extremities of Arabsat's reach – who in the pāst rarely got a glimpse of their brothers at the other end of the Arab world – reported the strongest audience interest. For although Arab stations have exchanged important televised news items in the past – via such international communications satellites as Intelsat – and have exchanged feature programs when feasible, the post-Arabsat period was the first time Arabs were able to conduct exchanges on such a regular, and prolific, basis. It was the first time, for example, that Mauritania, on North Africa's Atlantic coast, had been able to transmit to – and receive from – the Arabian Gulf.

This new flexibility was dramatically demonstrated in Muscat in November, 1985, during a summit meeting there of the Gulf Cooperation Council (GCC) – an economic and defense organization linking Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (See *Aramco World*, January-February 1984) – and, later, on Oman's national day. Because there is limited interest in the GCC in the West, and because space on Intelsat – a global satellite system on which the Arabs previously relied – was restricted, international TV coverage of the GCC was confined to one or two brief news items daily, and coverage of Oman's national day ceremonies – which took place at the same time as the summit meeting in Geneva between U.S. President Ronald Reagan and Soviet leader Mikhail Gorbachev – was even less. Thus Arab audiences, would normally have seen only what was transmitted internationally, or on specially arranged bi-lateral transmissions via international satellite to individual Arab states. In 1985, however, Oman TV was able to provide extensive coverage of both events in Muscat to all Arab states via an Arabsat satellite – regardless of what was happening internationally. "It's the best thing that's ever happened to us," an Oman TV producer told

an *Aramco World* reporter as he monitored incoming coverage of the Reagan-Gorbachev summit transmitted by Intelsat and, simultaneously, an exciting soccer match between two Gulf teams relayed by Arabs. Before the satellites went up, Arab broadcasters would only have received one – the summit. As it was, later that day, TV audiences in Oman saw both.

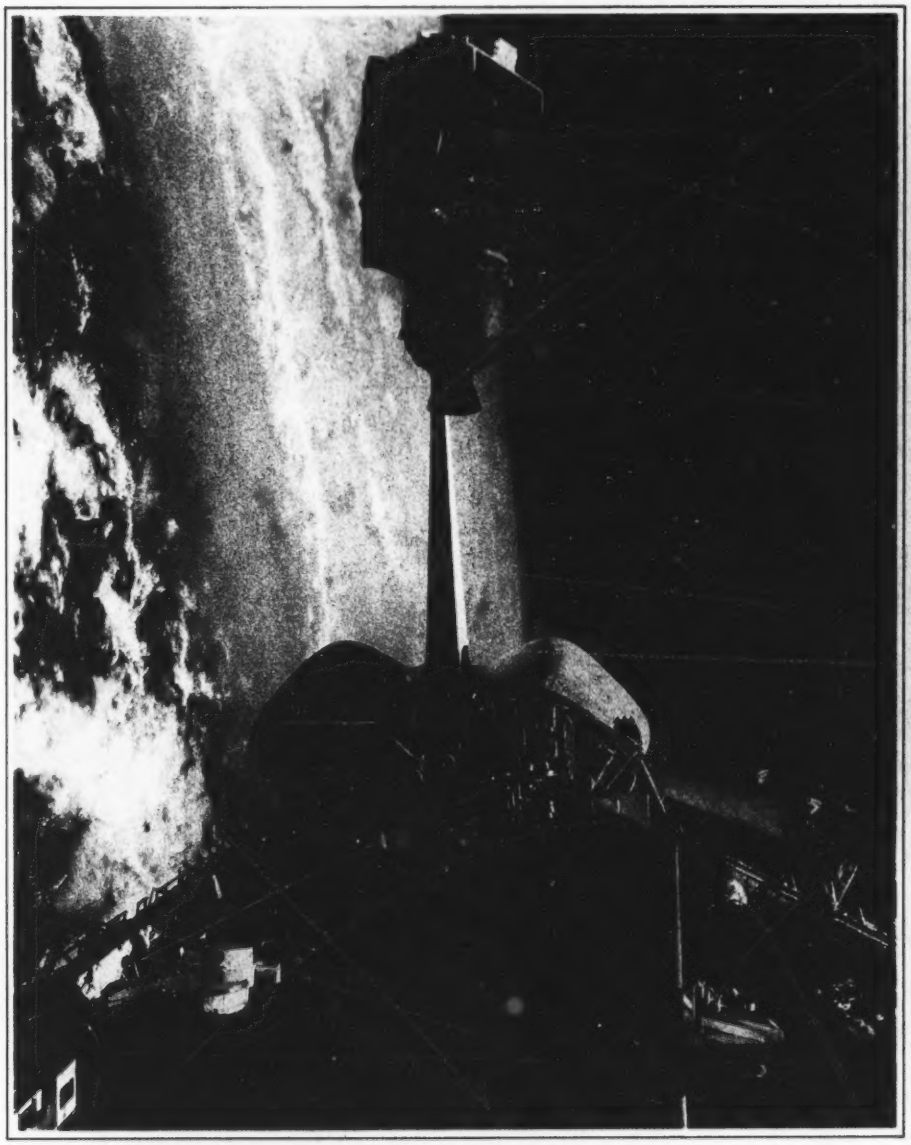
In the early 1980's, long before the first Arabsat satellites went up, the Gulf states had already made a new commitment to radio and television broadcasting. The existing networks and organizations, at least in the countries by the Arabian Gulf, had, in fact, charted a re - sponsible course for television's growth as early as the 1970's.

At that time, Gulf state ministers of information began regularly to discuss all aspects of the electronic media, and two organizations financed by Gulf governments were set up to foster broadcasting. One, Gulfvision, based in Riyadh, Saudi Arabia, was set up in 1977 to coordinate television activities by organizing news exchanges, program competitions, and special studies.

The other organization was the Arabian Gulf States Joint Program Production Institution. Headquartered in Kuwait, this group's main task is production of such programs for the region as the Arab version of "Sesame Street," *Iftah Ya Simsim* (See *Aramco World*, September-October 1979). Other programs focus exclusively on educational themes, dramatizing, for instance, such culturally sensitive topics as the adjustment of a non-Arab wife to local conditions, or the problems of a Gulf resident in the West.

In the late 1970's and early 1980's, indigenous television programming expanded so swiftly that the trend in 1986 was away from European and American programming – and even away from films and videotaped programs from non-Gulf Arab countries. One reason is that many contemporary Western programs are unacceptable in Muslim countries. Another is the belief that many of these productions do not explore problems relevant to the Gulf – or do not use Arabic common to the area, a serious matter in a region where language is revered.

TV's technical system for five Gulf countries is the Phase Alternating Line, or "PAL," system invented in Germany.



Although Saudi Arabia uses the French Sequential and Memory (SECAM) color system internally, the kingdom transmits in PAL color to neighboring countries.

Radio broadcasting too, has become more sophisticated in terms of both technical quality and programming, and every country had begun to present programs of both Western and Arab music, drama, public affairs and news. In most cases, Gulf states also transmit programs in both Arabic and foreign languages via short wave for listeners in other parts of the world. (Conversely, there is widespread international radio listening among Gulf residents: 44 international broadcasters transmit to the Arab world in Arabic.)

By 1986, television in Kuwait – one of the forerunners of television in the Arabian Gulf – had reached an advanced state of technical and artistic quality and the new Saudi Arabian television complex in Riyadh, completed in 1982, is probably one of the most spacious and modern in the world, with state-of-the-art equipment unmatched in most Western countries.

Arab news agencies are also well placed now – after a decade of intensive development – to make good use of Arabsat satellites to further reduce the influence of international news agencies in the Arab world.

Science : The Islamic Legacy

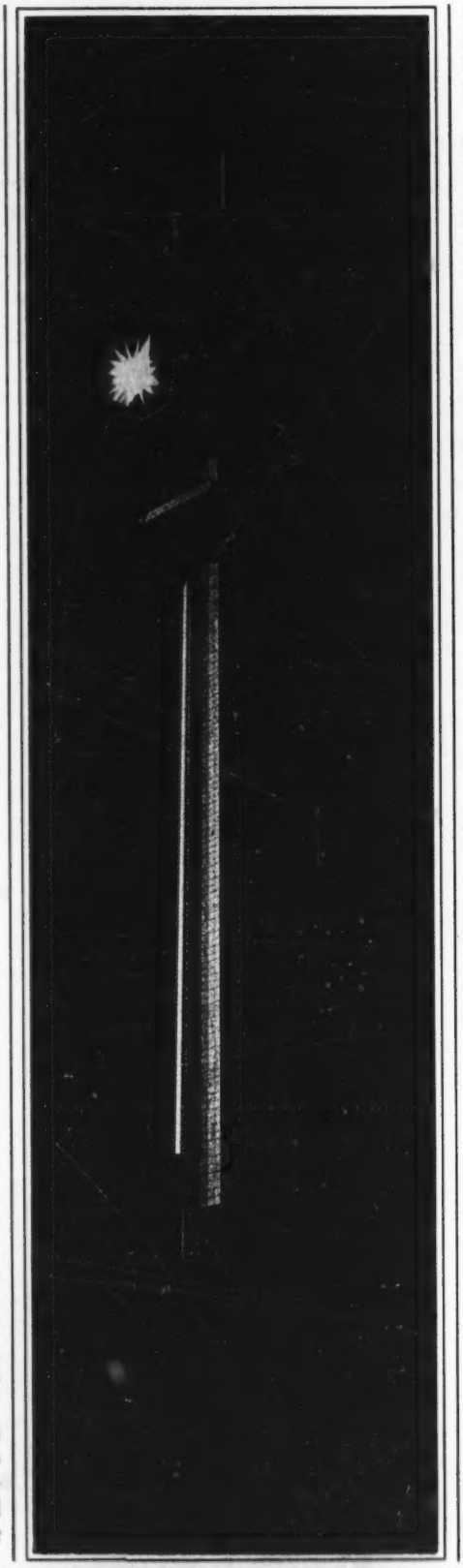
For many years the coverage and dissemination of news about and in the Arab East was largely in the hands of outsiders. News agencies such as the Associated Press (AP), United Press International (UPI), Reuters, Agence France Presse (AFP) and the Soviet News Agency (TASS), plus correspondents and cameramen for the major newspapers, magazines, radio stations and television networks in America and Europe, provided 90 percent of the world's day-to-day news. AP, UPI, AFP and Reuters alone sent 34 million words a day chattering over teleprinters in newspaper offices, banks, boardrooms and brokerage houses, TV newsrooms and government offices.

But since these agencies reflect the interests of their *readers* rather than the interests of the areas involved, coverage of many parts of the world tended to be incomplete and oversimplified, and, as a result, distorted.

Critics charged, for example, that by dwelling on crises, corruption and confrontation in the Third World, the international agencies make it difficult for poor countries to secure foreign capital and economic aid. Furthermore, it is argued, since AP, UPI, AFP and Reuters usually look at everything through the eyes of the Americans, British or French, Third World nations get little chance to get *their* views across – even to their own peoples.

In the late 1960's and the early 1970's, Arab governments in particular came to believe that they needed more news and information about events in their own regions. Simultaneously, a rapidly increasing domestic demand by the Arab media for foreign news began to develop. Because oil-based affluence had triggered a publishing boom in the Arab states, local newspapers, journals and magazines proliferated, and both television and radio networks were extended throughout most countries in the Arab world.

In response, Arab agencies began to push hard to fill the gap: by the 1980's Egypt's Middle East News Agency (MENA) was transmitting 185,000 words daily to 25 countries. But none was able to muster the resources to rival the "big four" and despite growth, domestic demand still could not support a commercial news agency. Existing international press agencies were not only able to provide the local media with most of the overseas coverage they then required, but could do it inexpensively. Individual governments, therefore, began to set up their own national news agencies.



In setting up national news services, different Arab states, of course, had differing objectives in mind. The Saudi Press Agency (SPA), for example, covers Saudi Arabia for the world and covers the world – or key parts of it – for Saudi Arabia, particularly developments with any bearing on, or reference to, Saudi Arabia and its government.

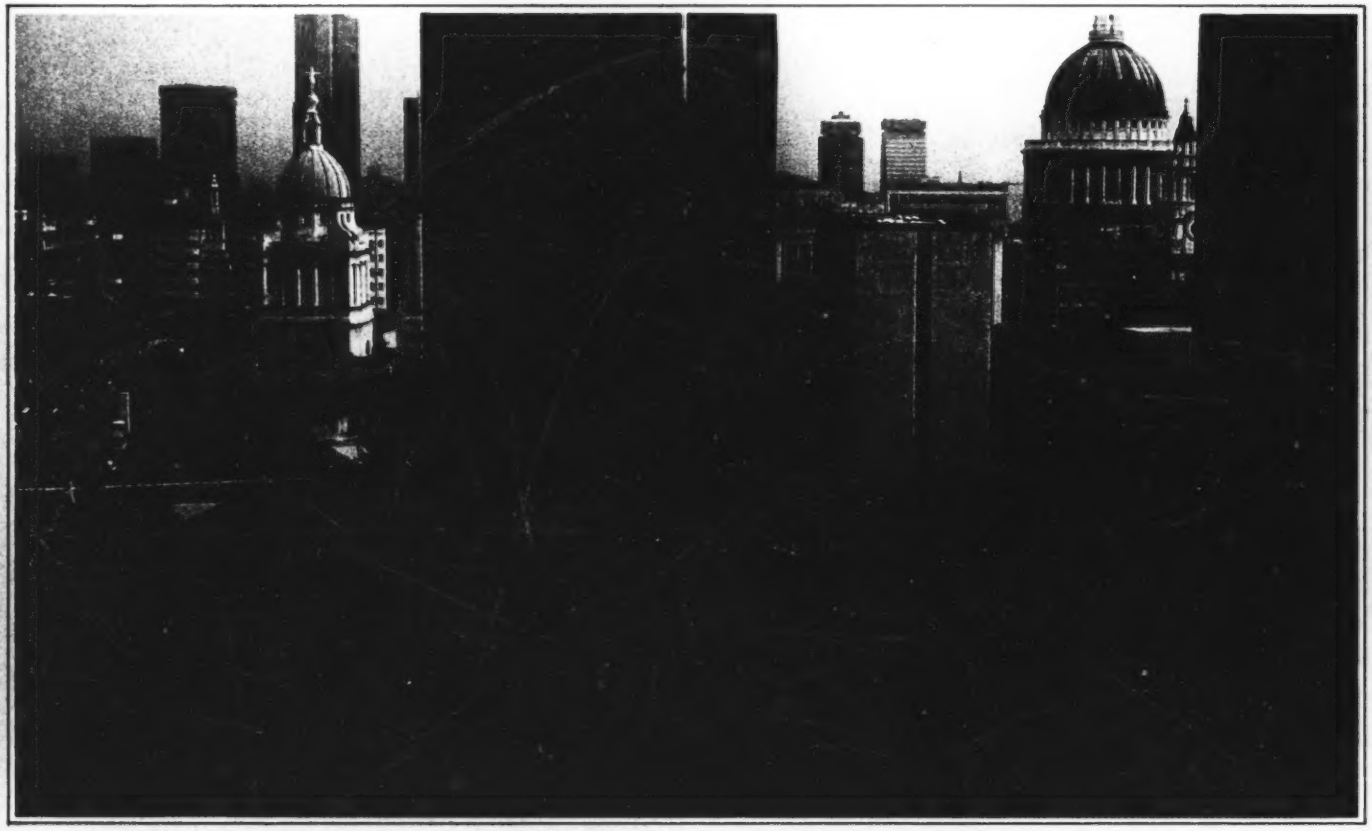
SPA has overseas bureaus in Beirut, Sanaa, Cairo, Tunis, Ankara, Karachi, London and Washington – all filing news to SPA headquarters in Riyadh – plus staff correspondents in other Arab cities and countries. SPA's output for both its domestic and overseas subscribers originates in, and is transmitted twice daily from Riyadh in Arabic and English to subscribers abroad – several thousand words a day, covering every aspect of the kingdom's day-to-day development considered newsworthy.

Formed in 1960, SPA had a staff of about 400 by 1986 and its output is required reading for anyone who writes, broadcasts or comments on Saudi affairs.

The Kuwait News Agency (KUNA) is another example. Following a highly professional news policy of balanced and objective reporting, KUNA's output is characterized by precision and speed: an average of 600 news items every day in Arabic and English, plus special reports and analyses and a separate bulletin sent daily to all Kuwaiti embassies and missions abroad. The agency's total daily output averages around 50,000 words – one of the largest volume-outputs among the Arab agencies – and is transmitted on its own communications system throughout Europe, the first such system to be set up by an Arab wire service.

KUNA, which began its operation in 1978, opted from the first for the most sophisticated means of communications available. By 1985, the agency was using 16 direct satellite lines to carry and transmit its newscasts abroad and 24 high frequency waves to beam its English and Arabic services.

KUNA has 15 foreign bureaus and its Kuwait headquarters, manned by 39 editorial desks, has exchange arrangements with 45 foreign news agencies. In 1985



KUNA's plans included extension of its 10-hour English overseas service to 18 hours a day and local Arabic transmissions from 16 hours to 24 hours a day.

The smaller Arab agencies are not to be compared with such larger operations as those sponsored by Kuwait and Saudi Arabia. Nevertheless, some have carved out reputations recognized outside their domestic borders. WAMPRESS, the official news agency of the United Arab Emirates, for example, has won an acknowledged position for its expertise on the oil industry in the Gulf; its stories and coverage in this field are prime source material. And the Qatar News Agency (QNA), reaching far beyond its national horizons, was, in the early 1980's, a leading sponsor of a major international conference in Paris concerned with media and information matters in the Middle East.

Although each national news agency does tend to stress the interests and points of view of its mother country, there are also genuine efforts to distribute good, accurate coverage of Arab affairs. Arab news agencies, moreover, through the Federation of Arab News Agencies (FANA), are building up a research capacity to supply background material, statistical data and information studies, in addition to news. In October 1984, FANA initiated a new service to Europe, through the Kuwait News Agency – which compiles news and reports from all FANA agencies and then transmits them through its Vienna bureau to 23 national European news agencies for FANA.

The president of FANA, Barges Hamoud al-Barges, who is also chairman and director general of the Kuwait News Agency, told *Aramco World* in 1985 that

Arab news agencies were eager and receptive to any developments in the communications field which might improve the transmission and dissemination of news to different parts of the world – such as the Arabsat satellites. In fact, the FANA president thought it very probable that Arab news agencies using other means of satellite communications would switch to the Arabsat network.

"Any consolidation of Arab efforts is a sign of strength. As such, the Federation of Arab News Agencies is one of the steps towards unification of Arab ranks and objectives. It also works as a preventive measure in the face of biased Western media, particularly the American one."

Arab newspapers will also be affected. For as Sa'id Hammoudi, the editor of the Iraqi daily *Al Thawrah* and the president of the Arab Journalists Union, said, Arabsat satellites can be used to print different editions of Arab newspapers simultaneously in different parts of the Arab world. He said that *Al Thawrah* was exploring this possibility as new technology can expand readership, and also improve the quality of journalism as a whole.

Science : The Islamic Legacy

Early in the 1980's, Arab news agencies and newspapers had to struggle to establish themselves as an integral part of the 20th-century miracle of mass communication. But with the launch of Arabsat satellites they were given the technological means to answer the classic question of the Arab in the desert: "What news?"

News, however, is only one aspect of communications. Arabsat capacities should also stimulate inter-Arab commercial activity and encourage the development and growth of pan-Arab companies. Indeed, the Arab businessman of the 1980's, with his microcomputers and instant communications, already looks back with disbelief at the days when he had to stand in a long queue at the local post office to send a telegram.

Rural areas in the Arab world will benefit in a different way. Shortages of qualified physicians can be eased by sophisticated telephone and television services that enable remote areas to pick up such transmissions from large medical centers.

Arab universities can also exploit Arabsat benefits. As far back as 1977, the Union of Arab Universities sent out a questionnaire to investigate the potential uses of the Arab space network and, according to Sa'ud Dahlawi, director general of Gulfvision, many universities, hoping to stimulate the activities of universities throughout the Arab world, called for more studies to implement the idea.

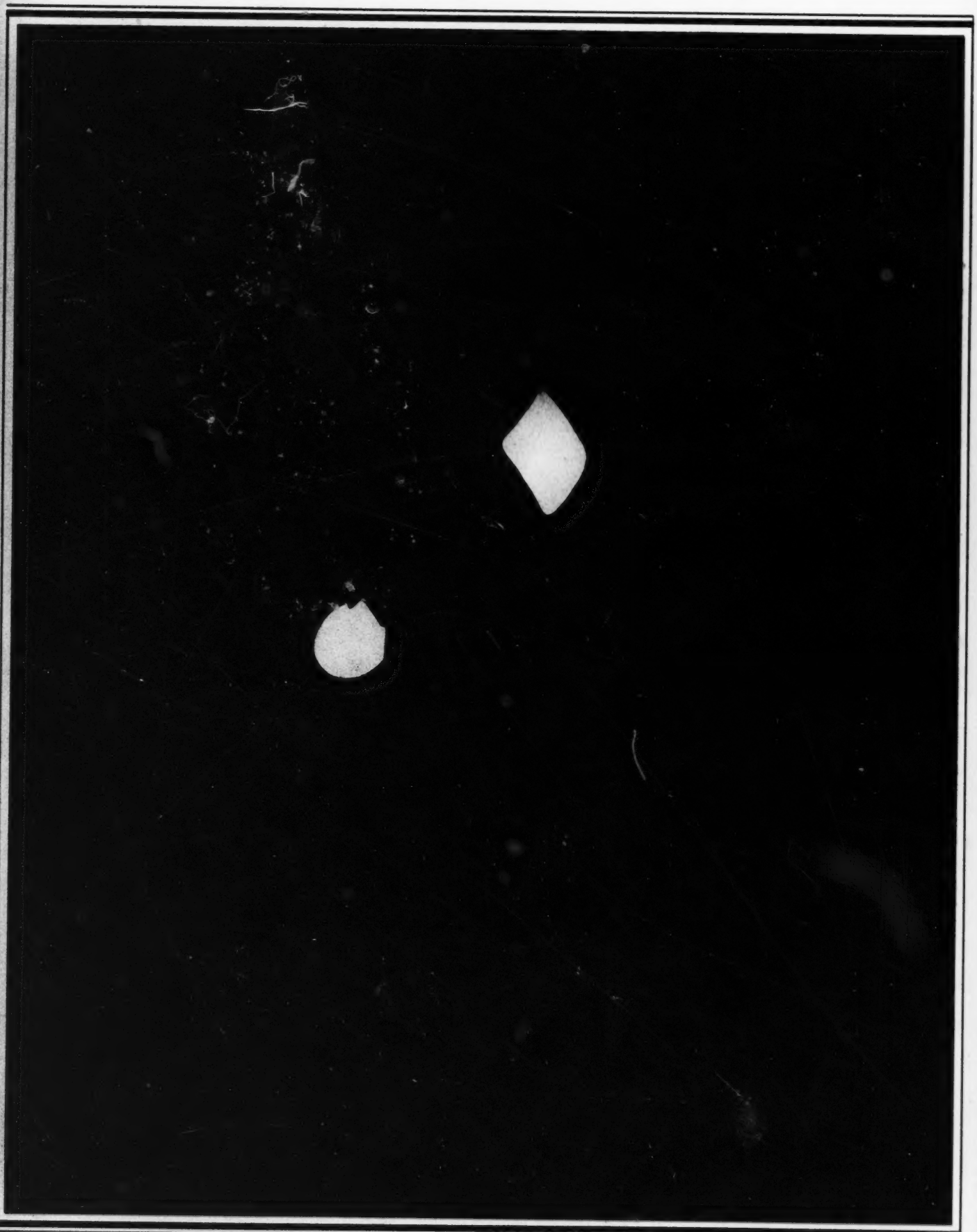
Since such possibilities excited communications ministries throughout the Arab world as soon as the idea was broached, there is already a broad consensus among Arab policy makers that the new space network should be given all the support it needs. In 1985, for instance, the minister of information in Iraq, Latif Naseef Jassim, emphasized Iraq's support of the project when he spoke to a visiting delegation from the United Nations Educational, Scientific and Cultural Organization (UNESCO). "This is a national strategic project which realizes the national ambitions of the Arab people..."

Tariq Almoayed, Bahrain's Minister of Information, made it clear too that his country expected a cultural and educational impact. "The new facility should be used for educational purposes despite the fact that such programs require urgent efforts," he said.

Similar enthusiasm regarding use of "community television" for adult education was expressed by Musa'ad al-Rawi, the head of an Arab organization set up to promote adult education. He proposed that new TV capacities be used to establish three "open universities" – i.e. televised classes open to all. The three would be the "Arab University, the Palestine University and the Gulf University," he said. Such education is urgently needed, he added, because conventional Arab universities may not be able to absorb the masses of high school graduates now coming along.

Dr. Sa'ad Labib, a veteran Arab broadcaster who ran a mass communication consultancy in Cairo, also called for adult education on the community television channel. "Such programs," he said, "would concentrate on developing badly needed professional skills and highlight the individual's role in society."

Eventually, Arabsat satellites will be used to link microcomputers and main-frame computers and to facilitate library services, electronic mail, instant data retrieval, financial services, airline bookings – all on a large scale.

Finally, there's science. One of Arabsat's goals is to encourage research in space communications; cooperation with NASA and the European Space Agency (ESA) has already provided numerous opportunities for Arab scientists and engineers to participate in space shuttle and Ariane flights either "on line" or at the launch site before, during and after each Arabsat-related shot.

With Arabsat satellites too, scientists in Arab countries will be able to undertake joint scientific research for the first time in centuries – as Dr. Muhammad Abdo Yamani, the former Saudi Minister of Information, reminded a media conference in Riyadh. Arabs, he said, should not forget the avant-garde role they played in developing the science of astronomy. "We must remember our pioneering role in ...astronomy and what our scientists have contributed to...the general foundations of these sciences." ■